PUU O UMI NATURAL AREA RESERVE

MANAGEMENT PLAN

Natural Area Reserves System

State of Hawaii

Department of Land and Natural Resources
1151 Punchbowl Street
Honolulu, Hawaii 96813

November 1989

EXECUTIVE SUMMARY

In 1970, Hawaii became one of the first states in the country to recognize the importance of its unique natural resources by establishing the State Natural Area Reserves System (NARS). Governor Waihee and the 1987 Legislature appropriated substantial new funding and legislative mandates to develop and implement management in the NARS. This plan describes the management program for the 10,142-acre Puu o Umi Natural Area Reserve, established in June 1986 by Executive Order 3367. The Reserve protects pristine native bog ecosystems and vital forest watersheds, which the surrounding communities depend on.

The Reserve is located in the Big Island's Kohala Mountains, beginning at sea level east of Waimanu Valley. Climbing sea cliffs to 1,400 feet, the Reserve continues onto the largely uneroded slopes of the Kohala shield volcano up to Puu o Umi at 5,260 feet. The Reserve comprises the majority of the Kohala Watershed; this water is captured and delivered for domestic and agricultural uses in the lands of Waimea, Hamakua, and coastal Kawaihae. The Reserve protects the head waters of Kaiwainui, Alakahi, Honokane Nui, and Kohakohau Streams; these water resources are tapped in their lower reaches. Eight natural communities, two of which are considered rare, were encountered during the management survey. Rare native plants and birds are also found within the Reserve.

Because of the size and inaccessibility of the Reserve, priorities for intensive management of key areas are based on the biological resources and the threats to those resources. Management activities over the next six years will focus on protecting the most intact native bog and forest ecosystems from feral pigs and non-native weeds. Management and public access into and through the Reserve will include improving roads to the Reserve boundaries and establishing and maintaining a Reserve-wide trail system. Four helipads and three management shelters will be built. Fence construction and aggressive removal of pigs are also planned.

The rapidly growing Kohala community will be informed about the Reserve and be given opportunities to become involved with appropriate management activities. A nature trail, Reserve brochure, and volunteer work program are planned. The effectiveness of management projects will be determined through long-term scientific monitoring.

A six-year implementation schedule is proposed to accomplish management objectives. An average annual budget of $170,000 will be needed over this time period. Once the pig threat is reduced, annual management costs should decrease. Agencies involved in the water development in the Reserve will be informed and involved in management activities wherever possible.

Contents
Puu o Umi Natural Area Reserve

ACKNOWLEDGEMENTS

Several organizations and individuals contributed information, guidance, and review for this management plan. Their cooperation and support is deeply appreciated. In particular, thanks to Sam Gon, Lyman Abbott, and Winona Char who participated in the field survey; Barrie Fox Morgan and all the hard working professionals at the Heritage Program of the Nature Conservancy who helped prepare the plan's resource information; Division of Forestry and Wildlife staff Jeanine Branam, John Giffin, Charlie Wakida and the rest of the Hilo staff for their expertise and logistical support; Deputy DLNR Chairperson Libert Landgraf; and Robert Lee and members of the Natural Area Reserves System.

Finally, sincerest thanks to Governor John Waihee, the State Legislature, and DLNR Chairperson William Paty for their desire and vision to preserve Hawaii's unique natural resources, and for their support of the Natural Area Reserves System.

Michael G. Buck
Natural Area Reserves System Coordinator

HAWAII NATURAL AREA RESERVES SYSTEM

DEPARTMENT OF LAND AND NATURAL RESOURCES

PUU O UMI NATURAL AREA RESERVE MANAGEMENT PLAN

I. INTRODUCTION

In 1970, Hawaii became one of the first states in the country to recognize the importance of its unique natural resources by establishing the State Natural Area Reserves System (NARS). The NARS is legally mandated to "preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites, of Hawaii" (HRS 195-1). To date, there are 18 reserves on 5 islands, occupying more than 108,000 acres of the state's most biologically diverse ecosystems.

Governor Waihee and the 1987 Legislature appropriated substantial new funding and legislative mandates to develop and implement management in the NARS. Directives were given to write comprehensive management plans for each reserve, based on the most current and relevant biological information available.

This plan describes the management program at the 10,142-acre Puu o Umi Natural Area Reserve, established in June 1986 by Executive Order 3367. The Reserve is noted for its intact montane bog ecosystems. The native forests in the Reserve act as vital watersheds for the surrounding communities. The plan consists of five parts:

- a brief **Introduction** to acquaint the reader with the project and how the plan was prepared;
- a **Resources Summary** describing the Reserve's natural resources;
- a **Management** plan describing programs recommended to maintain the Reserve's resources with an analysis of alternative actions and impacts;
- a **Budget Summary** listing the funds necessary to carry out the management plan; and
- **Appendices** describing resource information in more detail.

Three major sources of information were used to prepare this plan. The first was The Nature Conservancy's Hawaii Heritage database on rare species and unique natural communities. The second was a field inventory conducted in July 1988, specifically designed to collect data relevant to management of the Reserve's natural resources. The third was a review of this plan by qualified managers, planners, and biologists familiar with the area and its problems.

Survey crews spent seven field days gathering data along six transects, ranging from about 985 - 4,430 feet in length, and at three supplemental stations (Appendix 1 and Figure 1). Transects were intended to sample the range of natural vegetation types as described by J. D. Jacobi (1985). Detailed field forms were completed at sampling stations every 165 feet, noting the presence of natural communities, rare plants, native birds, feral ungulates, and weeds (Appendix 2). Aerial reconnaissance was used to collect resource information in the Reserve's more remote areas, where no transects were established.

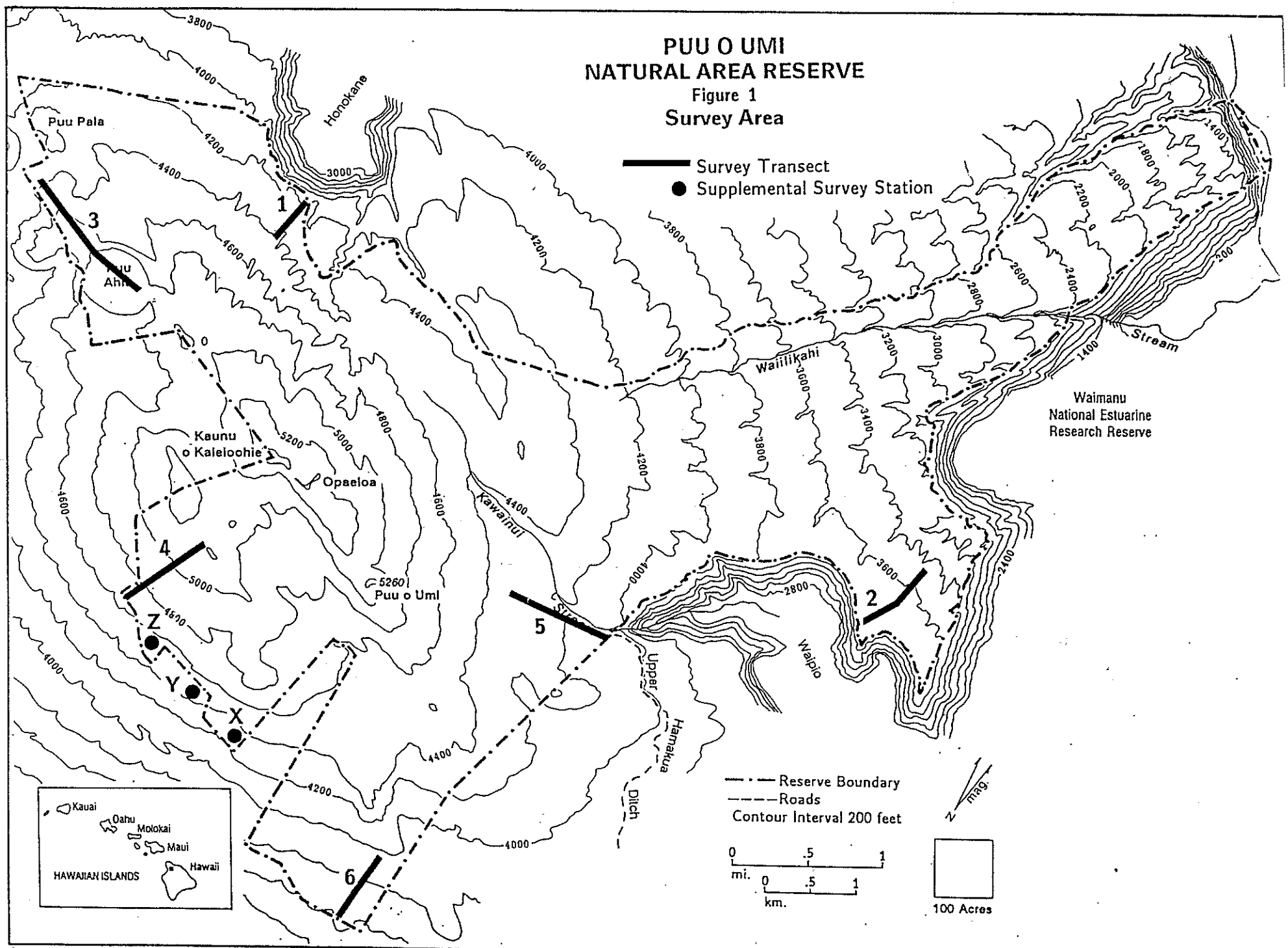
This survey was designed to gather management-oriented resource information over a large area in a short time period, and was not intended to be a comprehensive biological inventory. Sampling of small mammals, birds, and invertebrates was incidental rather than systematic. Detailed survey methods are available upon request. A list of plant species currently known from the Reserve is in Appendix 3; a list of bird species is in Appendix 4.

This plan is intended to establish long-range goals and management priorities at Puu o Umi Natural Area Reserve, and to describe specific programs and activities to be accomplished during the 1989-1991 biennium. This plan will be updated biannually to incorporate new knowledge and refine management concepts.

II. RESOURCES SUMMARY

A. General Setting

Puu o Umi Natural Area Reserve occupies 10,142 acres in the Big Island's Kohala Mountains. The Reserve begins at sea level west of Waimanu Valley, immediately climbing sea cliffs to 1,400 feet. The Reserve continues rising onto the largely uneroded slopes of the Kohala shield volcano. Maximum rainfall may exceed 150 inches annually (Giambelluca, Nullet, and Schroeder 1986). Waiilikahi and Kawainui streams begin in the Reserve and drop into Waimanu and Waipio valleys, respectively, on the Reserve's northeast and southeast boundaries. Honokane Valley drops away from the northern boundary of the Reserve's western-most


PUU O UMI
NATURAL AREA RESERVE
Figure 1
Survey Area
Survey Transect
Supplemental Survey Station
Puu Pala
Honokane
Puu Ahi
Kaunu o Kaleloohie
Opaeloa
Puu o Uml
5260
Kawainui
Stream
Waiilikahi
Waipio
Upper
Hamakua
Ditch
Waimanu
National Estuarine
Research Reserve
Reserve Boundary
Roads
Contour Interval 200 feet
mag.
mi.
km.
100 Acres
Kauai
Oahu
Molokai
Maui
Hawaii
HAWAIIAN ISLANDS

extension. The Reserve's southern leg reaches down to 3,600 feet elevation, above the Hawaii Preparatory Academy in the town of Waimea, and its highest point is 5,260 feet at Puu o Umi.

The region of the Kohala Mountains occupied by the Puu o Umi Reserve is largely inaccessible. The nearest highways are the Kohala-Waimea and Kawaihae-Waimea roads, which are about 1.5 miles away from the Reserve's south boundary. Jeep and foot trails along pipelines and the Kehena and Upper Hamakua Ditches approach and skirt the southeast and southwest sections of the Reserve. A rough trail connects the Kehena Ditch at the 4,400 foot elevation to two abandoned camps of the U.S. Geological Survey at the 3,000 and the 2,400 foot elevation.

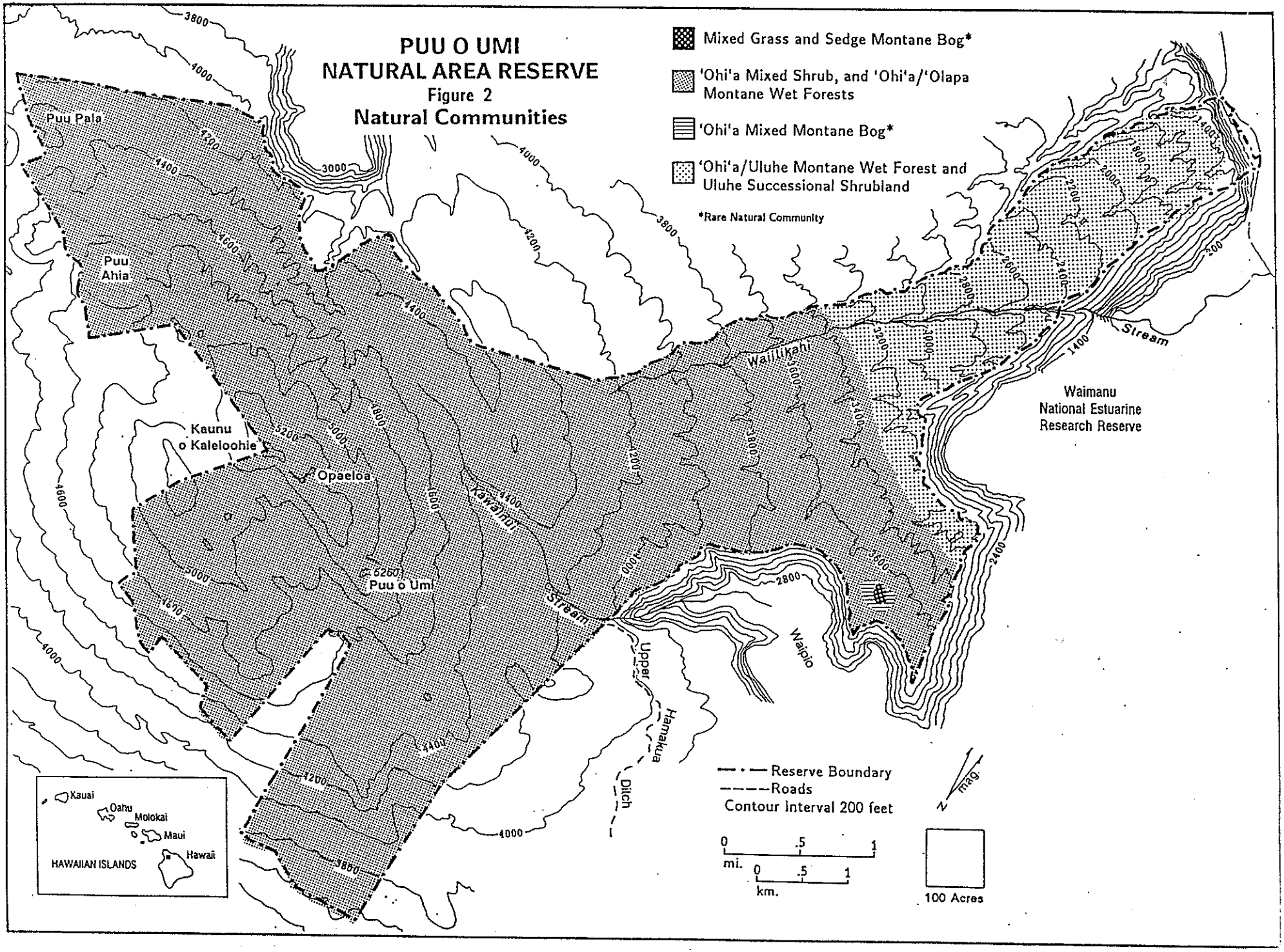
The Reserve comprises the majority of the Kohala Watershed. The water is captured and delivered for domestic and agricultural uses in the lands of Waimea, Hamakua, and coastal Kawaihae. Existing water resource facilities and projects were purposely excluded from the Reserve. The facilities include the Kohala Ditch and Tunnel, Kehena Ditch, Upper Hamakua Ditch, intakes, and diversion dams adjacent to the Reserve. The Reserve protects the headwaters of Kaiwainui, Alakahi, Honokane Nui, and Kohakohau Streams. These water resources are tapped in their lower reaches. Equally protected in the Reserves are the headwaters of Waihilau and Waiilikahi Streams, which are the major tributaries of Waimanu Stream. The adjoining Waimanu Valley is a National Estuarine Research Reserve.

B. Flora

Eight natural communities, two of which are considered rare, were encountered during this survey of Puu o Umi Natural Area Reserve (Table 1). For the purposes of this management plan, a natural community is considered rare if known from 20 or fewer locations worldwide. The two rare bog communities, Mixed Grass and Sedge Montane Bog and `Ohi`a Mixed Montane Bog, were located adjacent to each other in the Reserve's eastern extension at approximately 3,700 feet elevation (Figure 2). Appendix 3 lists native and non-native plant species known from the communities described in this plan.

The Reserve's natural community map (Figure 2) is designed to show the general distribution of vegetation types in the Reserve, and the vegetation type boundaries are not meant to be absolute. The map does not reflect complex transitions between communities, or small patches of communities within others.

Hawaiian bogs dominated by grasses or sedges, with few woody species (Mixed Grass and Sedge Montane Bogs), are known from fewer than five sites on Maui and Hawaii. Each of these rare bogs is dominated by a different but overlapping set of grasses and sedges. The dominant grass in the relatively simple


PUU O UMI
NATURAL AREA RESERVE
Figure 2
Natural Communities
Mixed Grass and Sedge Montane Bog*
'Ohi'a Mixed Shrub, and 'Ohi'a/'Olapa Montane Wet Forests
'Ohi'a Mixed Montane Bog*
'Ohi'a/Uluhe Montane Wet Forest and Uluhe Successional Shrubland
*Rare Natural Community
Puu Pala
Puu Ahia
Kaunu o Kaleloohie
Opaeloa
Puu o Umi
5260
Kawainui Stream
Waiilikahi Stream
Waimanu National Estuarine Research Reserve
Waipio
Upper Hamakua Ditch
Kauai
Oahu
Molokai
Maui
Hawaii
HAWAIIAN ISLANDS
Reserve Boundary
Roads
Contour Interval 200 feet
mag.
0 .5 1
mi.
0 .5 1
km.
100 Acres

community seen at Puu o Umi was kuolohia (Rhynchospora chinensis), and the moss, Sphagnum. Other grasses included `ohe (Isachne distichophylla), Dichanthelium cynodon and D. hillebrandianum. This bog contained few woody species, such as extremely stunted (often less than eight inches in height) `ohi`a (Metrosideros polymorpha), pukiawe (Styphelia tameiameiae), and `ohelo (Vaccinium dentatum).

TABLE 1
NATURAL COMMUNITIES OF PUU O UMI NATURAL AREA RESERVE

Natural Community	HHP Rank[1]	Acreage[2]
Carex alligata Montane Wet Grassland	3	x
* Mixed Grass and Sedge Montane Bog	1	5
Mixed Fern/Shrub Montane Wet Cliffs	3	x
*`Ohi`a Mixed Montane Bog	2	15
`Ohi`a Mixed Shrub Montane Wet Forest	3	+
`Ohi`a/`Olapa Montane Wet Forest	3	8,702
`Ohi`a/Uluhe Montane Wet Forest	3	1,420
Uluhe Successional Shrubland	3	#

* Rare Natural Community

[1] Key to Hawaii Heritage Program Ranks:
1 Critically imperilled globally (typically 1-5 occurrences)
2 Imperilled globally (typically 60-20 occurrences)
3 Restricted range (typically 21-100 occurrences globally)

[2] Acreages are based on vegetation types mapped in Figure 2. Due to mapping and survey constraints, complex transitions between communities, or small patches of communities within others, are not accounted for.
x Acreage too small or scattered to accurately estimate
+ Acreage included in `ohi`a/`olapa forest
# Acreage included in `ohi`a/uluhe forest

Vegetation in the second rare bog observed along Transect 2 was of low stature (less than 36 inches tall), dominated by a bog-form of `ohi`a, and by `uki (Machaerina angustifolia), growing out of a mat of Sphagnum moss. This `Ohi`a Mixed Montane Bog community is known from fewer than ten sites on the islands of Kauai, Molokai, Maui and Hawaii. On raised, better-drained portions of the bog seen in Puu o Umi Reserve, the `ohi`a was of higher stature (about 12 inches tall), and formed a canopy over a

variety of low shrubs including pukiawe and `ohelo. Species typical of bog habitat observed in this Puu o Umi example included a native violet (Viola maviensis), `ohe, kuolohia, Dichanthelium hillebrandianum, and D. cynodon. Uluhe (Dicranopteris linearis) and wawae`iole (Lycopodium cernuum) were observed occasionally on bog edges. This rare community is slow to recover from disturbance.

The other six native-dominated natural communities observed were typical of very wet, montane, windward slopes. Two of these communities, Carex alligata Montane Wet Grasslands and Mixed Fern/Shrub Montane Wet Cliffs, formed small scattered patches throughout the Reserve and were not mapped on Figure 2.

Carex alligata Montane Wet Grasslands are known from the islands of Kauai, Maui and Hawaii. Many of the low-lying, water-saturated sections of the Reserve seen during the survey were dominated by Carex alligata, often to the near exclusion of other species. Associated species included scattered `ohi`a, `olapa (Cheirodendron trigynum), `ohelo kau la`au (Vaccinium calycinum), and kuolohia.

Vegetation observed on the steepest slopes throughout the Reserve was dominated by ferns and shrubs, forming a Mixed Fern/Shrub Montane Wet Cliff community. Dominant species seen in Puu o Umi included `ama`u (Sadleria spp.), uluhe (Dicranopteris linearis, Sticherus owhyensis and Diplopterygium pinnatum), hapu`u (Cibotium spp.), and other ferns, with common native shrubs such as `ohelo kau la`au, pukiawe, and pilo (Coprosma dubens). Occasionally, shrubs such as na`ena`e (Dubautia plantaginea), pu`ahanui (Broussaisia arguta), koli`i (Trematolobelia grandifolia), and `ape`ape (Gunnera petaloidea) were seen. A variety of mosses, liverworts and smaller ferns, and herbs such as `ala`alawainui (Peperomia spp.) occurred under the mixed fern and shrub canopy.

Three distinct types of `ohi`a-dominated forest were observed during this survey forming a mosaic that covered 86 percent of the Reserve, or 8,702 acres (Table 1). `Ohi`a/`Olapa Montane Wet Forest comprised the majority of the `ohi`a-dominated forests. The `ohi`a/`olapa canopy reached 30 feet in height, but in many instances was shorter (less than 15 feet). Occasional large tree snags (8-15 inches diameter), probably `ohi`a, suggest that some areas of the forest have undergone dieback, and that the low stature canopy represents a regenerative phase. Dieback is a natural successional phenomenon in which older stands die synchronously, leaving gaps in the forest canopy. These gaps provide openings for subsequent `ohi`a regeneration.

Common associated species in the canopy of the `ohi`a/`olapa forest included kawa`u (Ilex anomala), kolea (Myrsine sandwicensis and M. lessertiana), alani (Pelea clusiifolia and

other species), and hapu`u (Cibotium glaucum and C. chamissoi). Another tree fern, meu (Cibotium hawaiiense), was observed infrequently, usually at elevations below those occupied by C. chamissoi. Uluhe ferns were often codominant. Shrub species included alani, pukiawe, pu`ahanui, na`ena`e, `ohawai (Clermontia spp.), manono (Hedyotis terminalis and H. hillebrandii), and pilo (Coprosma pubens and C. ochracea). Native ferns included ho`i`o (Athyrium sandwichianum), akolea (Athyrium microphyllum), Dryopteris spp., Asplenium spp., `ae (Polypodium pellucidum), `ama`u (Sadleria pallida and S. souleyetiana), and pala`a (Odontosoria chinensis). The ground cover was moss-dominated by Sphagnum sp., especially in poorly drained areas, but ground cover also included `ala`alawainui, and Cyrtandra paludosa. Maile (Alyxia oliviformis) was sometimes abundant. Aside from the unusual abundance of Sphagnum, the components of the `ohi`a/`olapa forest were typical of the community on other islands.

Forming a mosaic with the more prevalent `ohi`a/`olapa forest, the `Ohi`a Mixed Shrub Montane Wet Forest usually occupied the best drained areas on the Reserve's ridge tops. In the Reserve, the `ohi`a canopy of this forest generally exceeded 15 feet in height. There was often a secondary tree layer containing native species such as kawa`u, `olapa, kolea, alani (usually Pelea clusiifolia), and pilo. Under the tree layer was a discontinuous hapu`u layer and a well-developed native shrub layer containing such species as `ohelo kau la`au, pu`ahanui, pukiawe, `ohawai, kamakahala (Labordia hedyosmifolia), manono, alani, kolea, koli`i, pilo (Coprosma pubens), and saplings of `ohi`a and `olapa.

A diversity of native ferns was seen, including ho`i`o, akolea, `ae, wahine noho mauna (Adenophorus spp.), Asplenium spp., Dryopteris spp., and Vandenboschia davallioides. The herb layer contained mosses, liverworts, seedlings of a variety of plants, and `ala`alawainui. Native vines included maile, hoi kuahiwi (Smilax melastomifolia), and ma`ohi`ohi (Stenogyne calaminthoides). Epiphytes were well developed, including a variety of mosses, liverworts and ferns.

A broad expanse of `Ohi`a/Uluhe Montane Wet Forest was observed covering the north slopes leading to the Puu o Umi Reserve's seaward boundary. Patches of similar forest occurred adjacent to gulches or where ungulate damage was severe, such as the areas immediately adjacent to pasture lands. On the whole, the `ohi`a/uluhe forest occupied about 14 percent (1,420 acres) of the Reserve area. The composition of this forest was relatively simple; under an open canopy of `ohi`a, the ground cover was dominated by uluhe. Other elements of surrounding `ohi`a forests, especially `olapa and hapu`u, emerged above the thick uluhe mats.

Uluhe also forms a shrubland without association of an `ohi`a canopy, as it can rapidly dominate where there has been disturbance, such as landslides, fires, ungulate damage, or road cuts. Steep slopes and some `ohi`a dieback areas in the Reserve were dominated by these Uluhe Successional Shrublands. On moderate slopes, a variety of scattered low trees and shrubs were also present, including `ohi`a, `olapa, and pukiawe. On steeper slopes, the cover was almost entirely uluhe.

Of the five rare plant taxa reported from the Puu o Umi Reserve area, three have been verified within the Reserve's boundary recently (since 1972) (Table 2 and Figure 3). For the purposes of this plan, a species is considered rare and imperilled if it is known from 20 or fewer locations worldwide, or less than 3,000 individuals. The other two taxa may occur in the Reserve; both are known from adjacent areas. The fern Diplazium molokaiense was seen in 1983 during a survey of the Hamakua ditch area. The rare mint Phyllostegia floribunda has not been reported from the Puu o Umi area since 1911. Additional surveys, specifically designed for rare plants, may uncover these taxa, as well as other rare taxa not yet reported from the Reserve.

Thirteen other rare taxa are reported in literature for the area, but lack specific enough location information to include here (Appendix 3). Because many rare native plants lack unique Hawaiian or common names, scientific names are used throughout this section. Hawaiian names, where available, are provided in Table 2. Due to changes in taxonomy, some taxa currently listed as candidate species in the most recent Federal Register may no longer be considered rare by the Hawaii Heritage Program and their federal status is being reevaluated (Herbst pers. com.).

None of the three rare plant taxa reported to occur in the Puu o Umi Reserve is officially listed as endangered by the U.S. Fish and Wildlife Service (1987). Two of these taxa, Eurya sandwicensis and Pritchardia lanigera, were on the Federal Register as candidates for listing under their previous taxonomic treatment. Though their federal status is being reevaluated, they are still considered rare by the Hawaii Heritage Program. The other taxon, Pelea hawaiensis, is a candidate to be listed as endangered or threatened, and their taxonomy has been maintained by Wagner et al. (in press).

All three rare plant taxa confirmed within the Reserve boundary recently were seen during the survey (Table 2). Two vigorous Eurya sandwicensis shrubs were seen in `ohi`a/`olapa forest in the Reserve's south-central section (Figure 3); these shrubs had no flowers or fruit. This taxon is very similar to `ohelo (Vaccinium spp.), but has very small, fleshy nodding flowers that are pale yellow in color. Eurya sandwicensis is

TABLE 2
RARE PLANTS OF PUU O UMI NATURAL AREA RESERVE

Scientific Name[1] Former Name[2] (Common Name)	Current (Historic) Occurrences[3]	Federal Status[4]	HHP Rank[5]
*Eurya sandwicensis E. sandwicensis var. grandifolia (anini)	1(0)	- C1	2
*Pelea hawaiensis (alani)	2(0)	C1	2
*Pritchardia lanigera P. montis-kea (loulu)	1(0)	- C1	1

* Observed during 1988 survey.

[1] Wagner and Wagner (1987)
Wagner et al. (in press)

[2] Following taxonomy used in 1985 Federal Register

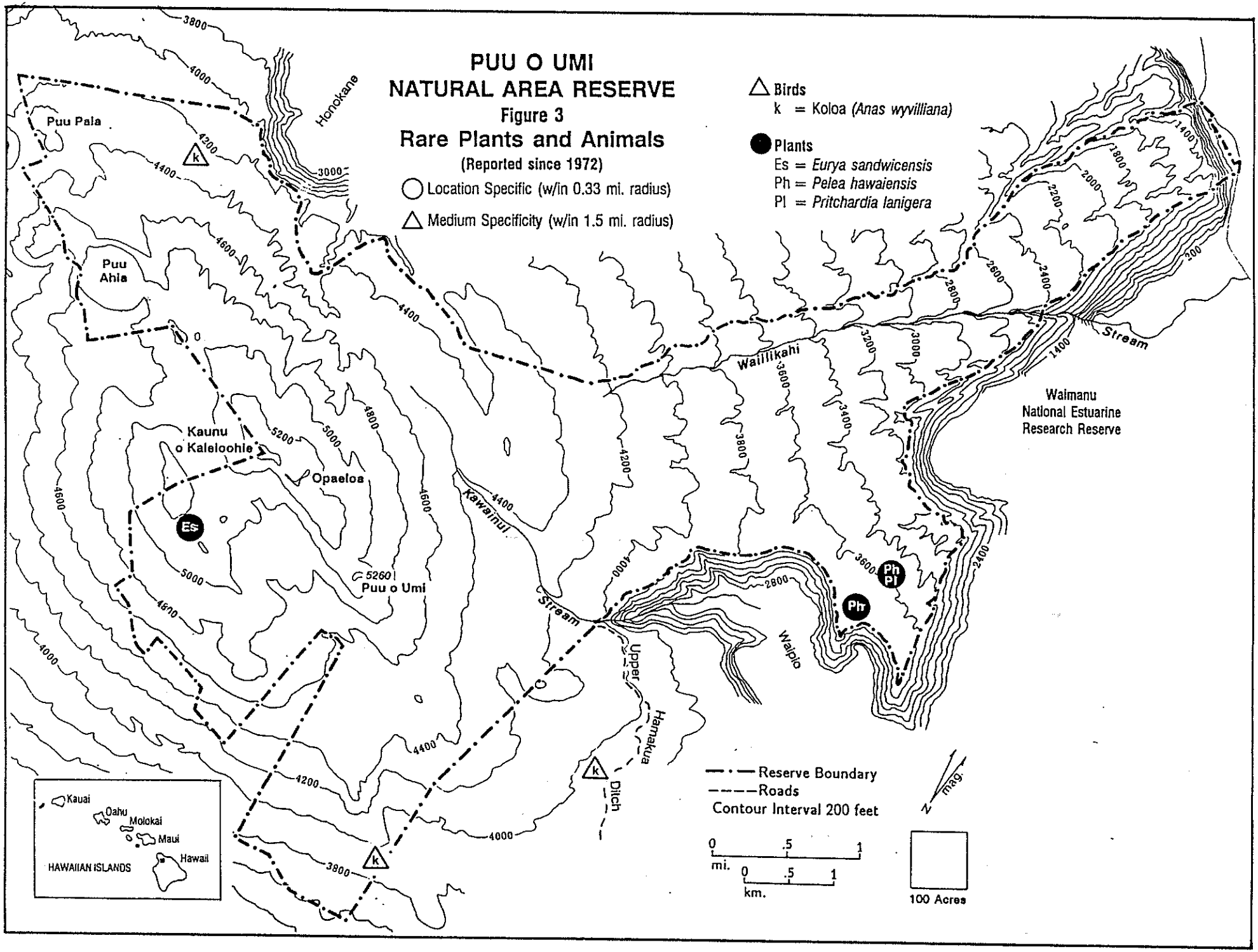
[3] Current occurrences reported since 1972

[4] Key to Federal Status (USFWS 1985, 1987):
C1 Candidate for endangered or threatened status
- No federal status. Described as rare by Hawaiian botanists and confirmed by Heritage data

[5] Key to Hawaii Heritage Program Ranks:
1 Critically imperilled globally (typically 1-5 occurrences)
2 Imperilled globally (typically 6-20 occurrences)

found scattered in mesic to wet forests on all of the major islands (Wagner et al. in press).

Pelea hawaiensis was seen at two stations along Transect 4, in `ohi`a/`olapa forest (Figure 3). Only one shrub was seen at each station. Neither shrub was flowering, but one was in bud. Flowers of this species are typically reddish in color. This taxon is found in dry and mesic forests of Molokai, Lanai, Maui and Hawaii (Wagner et al. in press).


PUU O UMI
NATURAL AREA RESERVE
Figure 3
Rare Plants and Animals
(Reported since 1972)
Location Specific (w/in 0.33 mi. radius)
Medium Specificity (w/in 1.5 mi. radius)
Birds
k = Koloa (Anas wyvilliana)
Plants
Es = Eurya sandwicensis
Ph = Pelea hawaiensis
Pl = Pritchardia lanigera
Puu Pala
Honokane
Puu Ahia
Kaunu o Kaleloohie
Opaeloa
5260'
Puu o Umi
Kawainui Stream
Waiilikahi Stream
Waimanu National Estuarine Research Reserve
Waipio
Upper Hamakua Ditch
Kauai
Oahu
Molokai
Maui
Hawaii
HAWAIIAN ISLANDS
Reserve Boundary
Roads
Contour Interval 200 feet
mi.
km.
mag.
100 Acres

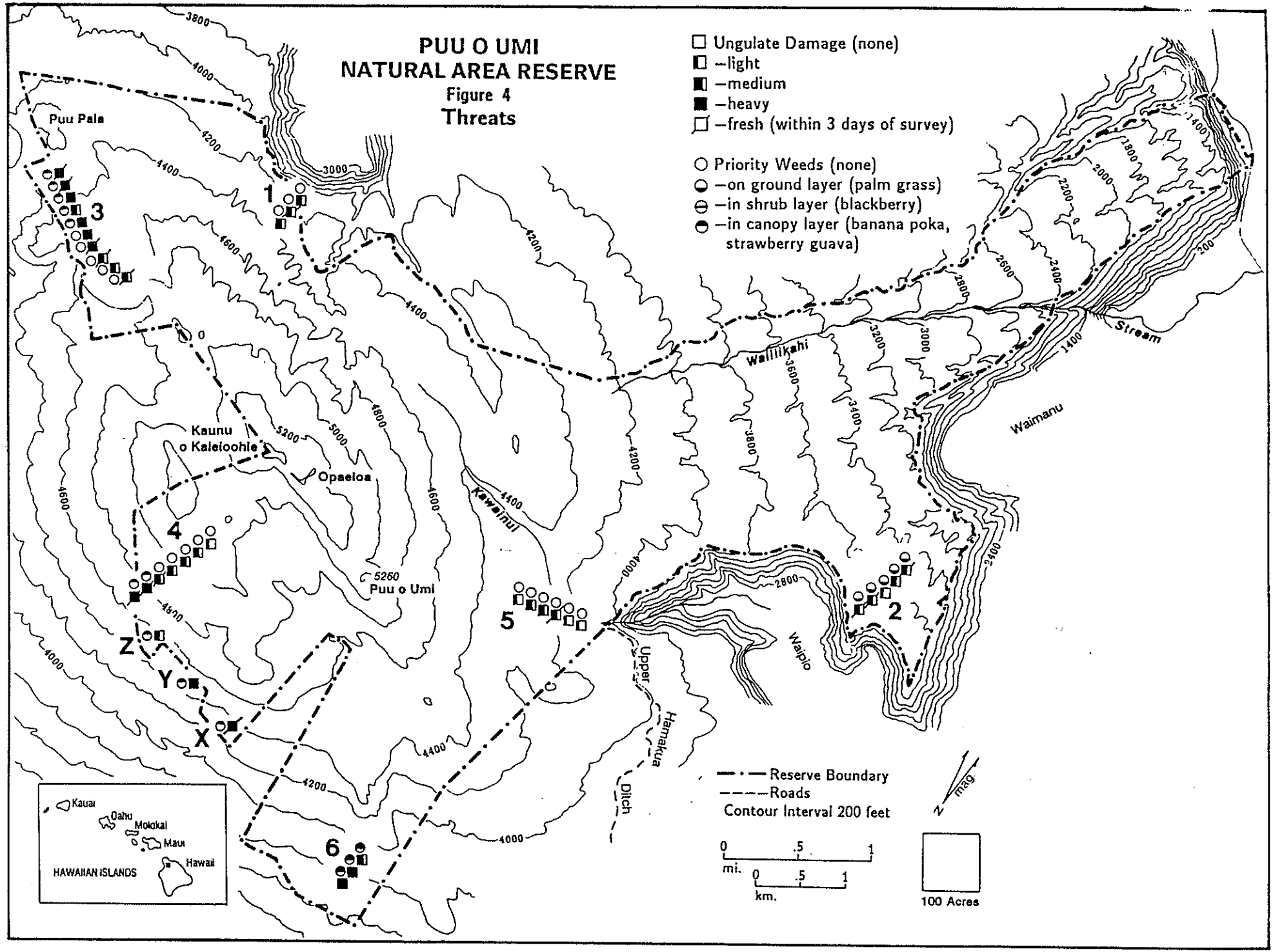
Only one individual of the rare palm Pritchardia lanigera was seen (from a distance) during the survey, just past the end of Transect 4 in Uluhe Successional Shrubland (Figure 3). Flowers of this taxon are typically small and inconspicuous, but borne on large fleshy stalks that curve outward from the main trunk. This palm is found only on the boggy plateau of the Kohala Mountains and on the windward slopes of Mauna Kea (Wagner et al. in press).

C. Fauna

Four species of native forest birds were observed during the survey. Forest birds were seen throughout all vegetation types in the Reserve, but were most prevalent in closed-canopy forests of `ohi`a and `olapa. `Elepaio (Chasiempis sandwichensis sandwichensis), `Amakihi (Hemignathus virens virens), `Apapane (Himatione sanguinea sanguinea), and `I`iwi (Vestiaria coccinea) all appeared abundant. `I`iwi, `Apapane and `Amakihi were observed feeding on the flowers of the non-native banana poka vine (Passiflora mollissima) near the edge of pastures, in numbers greater than those observed in native forest. This phenomenon has been observed before, and in this case was probably due to the lack of blooming `ohi`a at the time of the survey (less than ten percent of trees were estimated in flower).

Although not observed during this July survey, two rare bird species are known from the Reserve area. Hawaiian Hawk, or `Io (Buteo solitarius), has been reported along the Reserve's northwestern boundary. Hawaiian Duck, or Koloa (Anas wyvilliana), was sighted in the southeast extension of the Reserve (Figure 3). During the U.S. Fish and Wildlife Service's Hawaii Forest Bird Survey, a mottled brown-light duck, tentatively identified as a Koloa, was observed in the western-most section of the Reserve (USFWS n.d.). Additional sightings of both `Io and Koloa have occurred nearby, but outside the Reserve (Banko 1980, 1987).

Newell Shearwater, or `A`o (Puffinus newelli), is listed as threatened by the U.S. Fish and Wildlife Service (1987). It is thought that this rare seabird has established colonies in the Kohala Mountains, although none have been confirmed. Records of sightings and calls suggest that `A`o colonies exist within the Hamakua and Kohala forests, but that these colonies are very dispersed and probably contain very few individuals (Kepler et al. 1979). Because the birds are active at night and nest in dense rain forest on steep slopes, nesting sites are very difficult to locate. There is a possibility that a breeding colony exists in the Reserve's northern, seaward finger; calls were heard during the night in August 1977 at 2,440 feet, west of where Waiilikahi Stream drops into Waimanu Valley (Hall 1978). During September 13-15, 1977, `A`o were heard in Waimanu Valley (Kepler et al. 1979).


PUU O UMI
NATURAL AREA RESERVE
Figure 4
Threats
Ungulate Damage (none)
–light
–medium
–heavy
–fresh (within 3 days of survey)
Priority Weeds (none)
–on ground layer (palm grass)
–in shrub layer (blackberry)
–in canopy layer (banana poka, strawberry guava)
Puu Pala
Kaunu o Kaleloohie
Opaeloa
5260
Puu o Umi
Kawainui
Stream
Walilikahi
Waimanu
Waipio
Upper
Hamakua
Ditch
Reserve Boundary
Roads
Contour Interval 200 feet
mag
0 .5 1
mi.
0 .5 1
km.
100 Acres
Kauai
Oahu
Molokai
Maui
Hawaii
HAWAIIAN ISLANDS
1
2
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X
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Z

banana poka, which is the Reserve's most serious weed problem. Non-native plants degrade the quality and integrity of native plant communities, threatening the existence of species that rely on the forest for survival. This disturbance also threatens the quantity and quality of water originating from the forest watershed. Control of feral pigs is the essential first step in maintenance of the Reserve's native plant communities. Aggressive control activities are critical for effective long term reduction of the pig population. (See Management Programs Priority #1 - Ungulate Control Program.)

3) Many non-native plants observed in the Reserve are shade intolerant and pose no major problem as long as the native canopy and ground cover remain intact. Several non-native weed species (e.g. banana poka) in the Reserve, however, form monotypic stands and displace native vegetation over large areas. These are priority weeds for management. Weed control activities will focus on priority weeds within specific management areas, and on localized populations of priority weed species, which could spread if not controlled. (See Management Programs Priority #2 - Non-native Plant Control Program.)

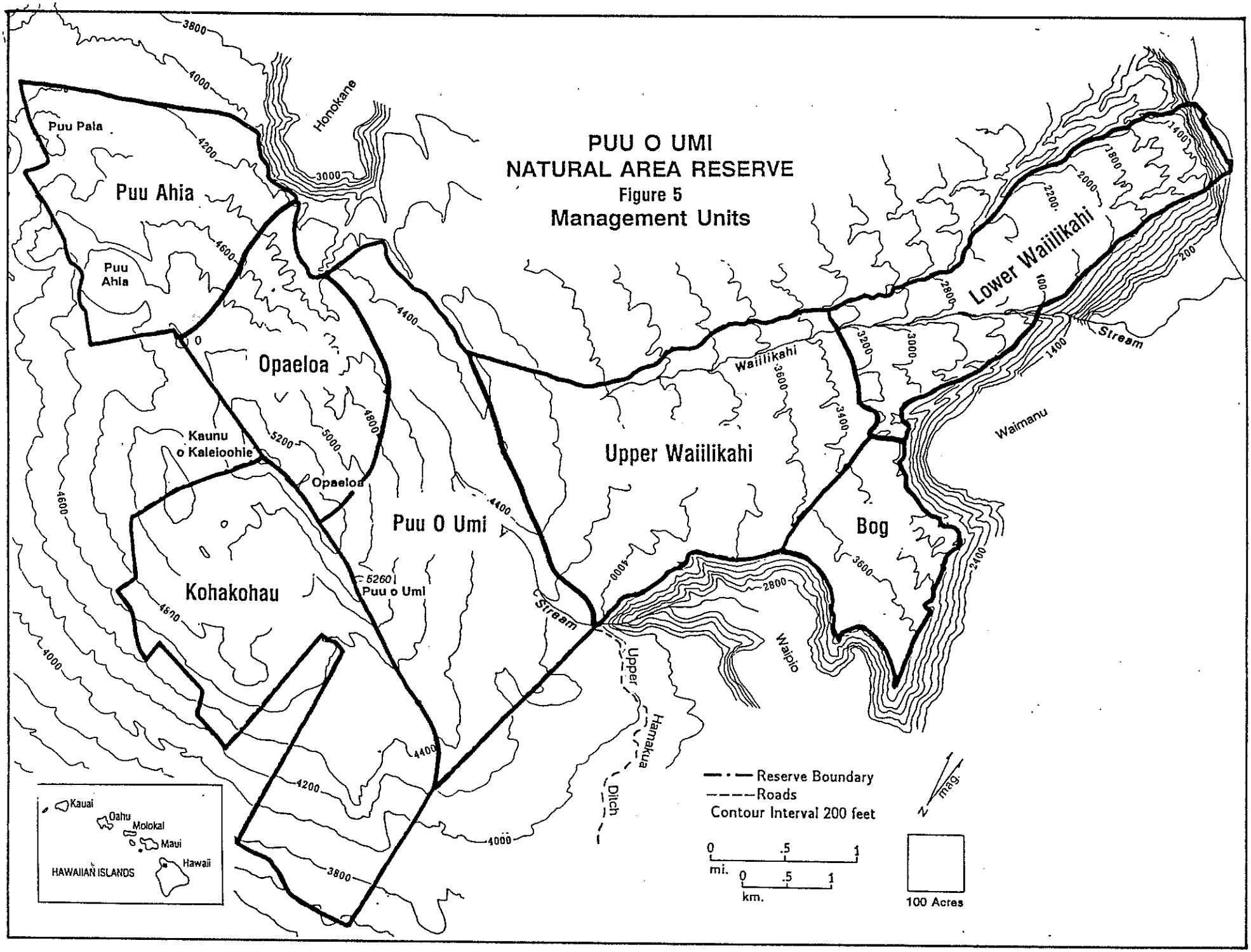
4) The Reserve encompasses the majority of Kohala Watershed and protects the head waters of Kaiwainui, Alakahi, Honokane Nui, and Kohakohau Streams. These water resources are tapped in their lower reaches for domestic and agricultural uses. Protection of the Reserve's native ecosystems will also protect this valuable watershed. Agencies involved in the water development activities should be informed and involved in Reserve management activities wherever possible.

5) The rapidly growing Kohala community should be informed about the resources and involved with appropriate management activities in the Reserve. Improved access and a maintained trail system in the Reserve will help. A nature trail is recommended for Waipahoehoe Gulch. A cadre of volunteer Reserve managers from the local community should be developed (See Priority #4 - Volunteer Support Program).

B. Management Unit Descriptions

The Reserve has been divided into seven management units (Figure 5). Descriptions of each unit follow, with an outline of problems, key program features, and management priorities:

Bog Unit (630 acres) - This unit contains the two rare bog communities and three other `ohi`a forest communities. It has the highest priority for feral pig control and fencing is recommended. A permanent helipad is planned to expedite management work. The headwaters of Waihilau Stream are here.


PUU O UMI
NATURAL AREA RESERVE
Figure 5
Management Units
Puu Pala
Puu Ahia
Puu Ahia
Honokane
Opaeloa
Kaunu o Kaleloohie
Opaeloa
Puu O Umi
5260
Puu o Umi
Kohakohau
Upper Waiilikahi
Waiilikahi
Stream
Lower Waiilikahi
Stream
Waimanu
Bog
Waiolo
Upper Hamakua Ditch
Reserve Boundary
Roads
Contour Interval 200 feet
mag.
0 .5 1
mi.
0 .5 1
km.
100 Acres
Kauai
Oahu
Molokai
Maui
Hawaii
HAWAIIAN ISLANDS

Kohakohau Unit (2,242 acres) - The unit includes a mosaic of `ohi`a forest communities. It has the highest priority for access improvement and non-native plant control (especially banana poka). The establishment of two improved access routes from the highway to the Reserve's lower boundary and two management trails within the unit are recommended. The Summit Trail will define the unit's northern boundary. A management shelter is planned near the junction of the Summit and Eke trails (Figure 6). The unit contains Kohakohau Stream's headwaters.

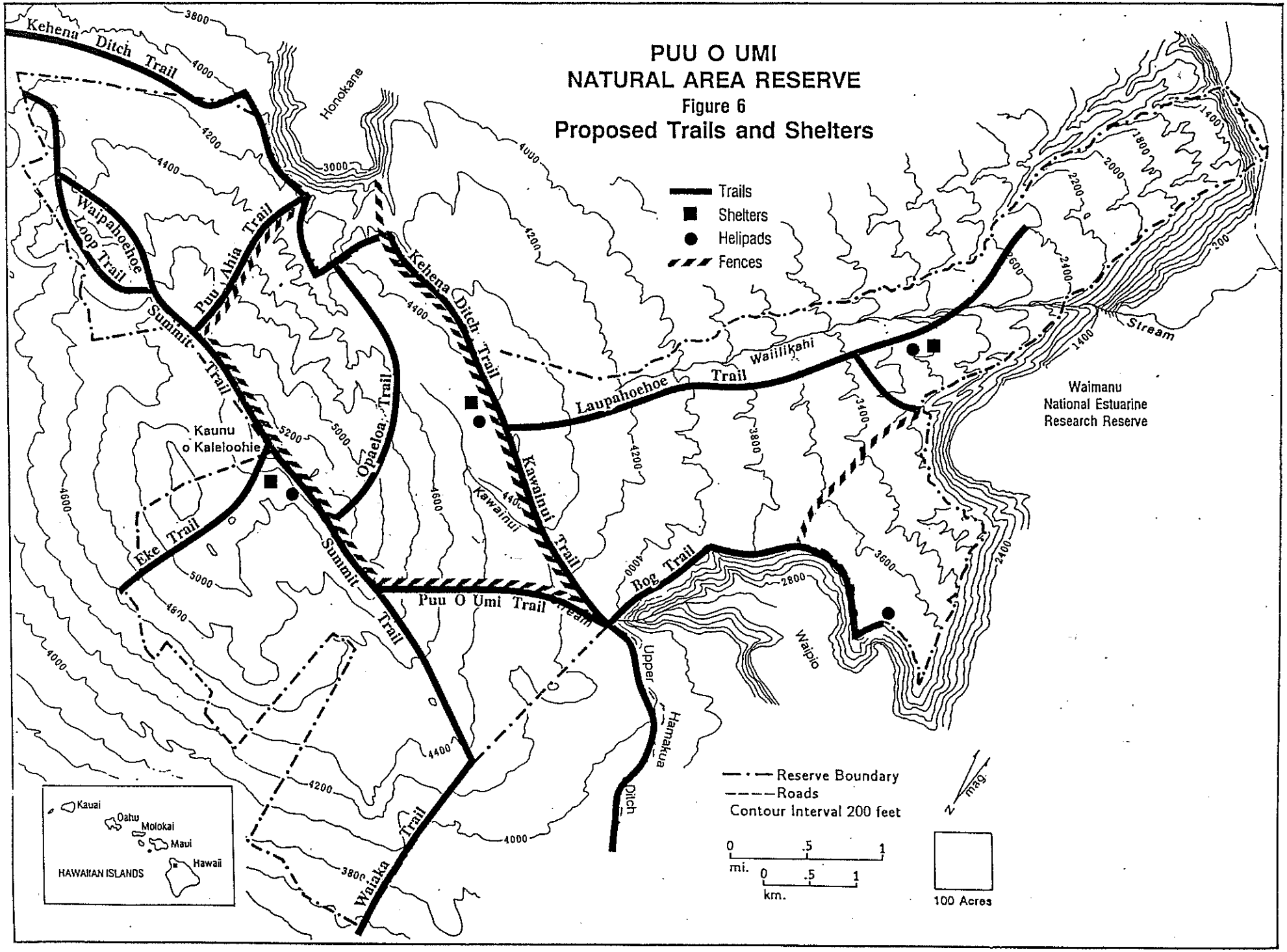
Lower Waiilikahi Unit (1,380 acres) - The unit includes mostly `Ohi`a/Uluhe Montane Wet Forest and Uluhe Successional Shrubland communities. A management shelter is recommended at the "new USGS camp site" along an improved Laupahoehoe trail (Figure 6).

Opaeloa Unit (885 acres) - This unit is dissected with small streams in steep and difficult terrain and includes a mosaic of `ohi`a forest communities. The boundaries of the unit will be the newly established Opaeloa, Puu Ahia, and Summit trails (Figure 6). The headwaters of two tributaries of Honokane Nui Stream are within the unit. The unit is relatively unexplored and has high priority for additional survey work, focussing on location of pristine native communities and feral pig control. Fencing is recommended.

Puu Ahia Unit (1,310 acres) - The unit contains a mosaic of `ohi`a forest communities, which contain rare plants. Puu Ahia is of geological interest. The headwaters for a tributary of Honokane Nui Stream are within the unit. The unit has a high priority for access improvement and public education. The planned Waipahoehoe Loop Trail has potential as a nature trail (Figure 6).

Puu o Umi Unit (1,705 acres) - The unit contains a mosaic of `ohi`a mixed shrub and `ohi`a/olapa forest communities. It is the heart of the Reserve, buffered from many of the disturbances around the Reserve. Puu o Umi is the highest point in Reserve. The unit protects the headwaters of Alakahi, Kawaiki, Kawainui, and Honokane Nui Streams. The unit is relatively unexplored and has the highest priority for additional survey work, focussing on location of pristine native communities and feral pig control. A management shelter and helipad are planned at the junction of Kehena Ditch, Laupahoehoe, and Kawainui trails (Figure 6). Fencing is also recommended.

Upper Waiilikahi Unit (1,990 acres) - The unit contains a mosaic of `ohi`a forest communities and protects the headwaters for Kaiwainui, Waihilau, and Waiilikahi streams. It is an important buffer zone for the higher elevation units. The unit will encompass the major trails to the Bog Unit and lower management shelter, via the Laupahoehoe, Kawainui, and Bog trails.


PUU O UMI
NATURAL AREA RESERVE
Figure 6
Proposed Trails and Shelters
Trails
Shelters
Helipads
Fences
Kehena Ditch Trail
Honokane
Waipahoehoe Loop Trail
Puu Ahia Trail
Summit Trail
Kaunu o Kaleloohie
Opaeloa Trail
Eke Trail
Kehena Ditch Trail
Kawainui
Kawainui Trail
Laupahoehoe Trail
Waillikahi Stream
Waimanu National Estuarine Research Reserve
Puu O Umi Trail
Bog Trail
Waipio
Upper Hamakua Ditch
Waiaka Trail
Reserve Boundary
Roads
Contour Interval 200 feet
mag.
mi.
km.
100 Acres
Kauai
Oahu
Molokai
Maui
Hawaii
HAWAIIAN ISLANDS

C. Management Programs

The following four management programs support the long-term goals for the Reserve. A six-year implementation schedule is proposed. Although the programs are listed by priority, they fit together to form an integrated management package.

Priority #1 - Ungulate Control Program (PUO-RM-01)

GOAL: Eliminate ungulates in select areas of high biologic value. In the rest of the Reserve, reduce the impact of ungulates to a level that prevents further degradation of the Reserve's native ecosystems and allows the greatest possible recovery of the Reserve's native species.

Statement of the Problem: Feral pig control is critical to the survival of native ecosystems and protection of the forest watersheds in the Reserve. There are many techniques for pig control. The NARS manager will need the flexibility to use all the tools available, as the Puu o Umi Reserve presents different vegetation types, topographic features, access problems, and resource protection priorities. These tools include public hunting, fencing, staff hunting, and snaring.

A component of the feral ungulate control program is systematic monitoring. Monitoring will evaluate changes in levels of ungulate damage, the effectiveness of the management program in reducing damage, and the recovery of native vegetation (see Priority #3 - Monitoring Program).

Feral pig activity was observed on all transects in the Reserve (Figure 4). The intensity of damage varied by location and vegetation type. Pig disturbance was limited to the periphery of the pristine bogs. Damage was more prevalent in the better-drained examples of the Carex wetlands. The steepest slopes of the mixed fern/shrub cliff community were inaccessible to pigs, but trails and damage on slopes adjacent to less steep terrain were evident. Pig damage was light to moderate in the `Ohi`a Mixed Shrub Montane Wet Forest community, and regeneration of understory components was observed. Once pigs are controlled, this resilient forest community may resist weed invasion.

Pig damage in the `Ohi`a/`Olapa Montane Wet Forest was generally old and light. A few sections of moderate, fresh damage were noted, however, in which browsed vegetation and rooting was evident. Species such as the Hawaiian orchid Liparis hawaiensis, `ohawai (Clermontia spp.), and pa`iniu (Astelia menziesiana) were present only as epiphytes, suggesting that pigs have already removed these species from the ground cover. Pigs move readily through the `Ohi`a/Uluhe Montane Wet Forest, plowing

tunnels under the uluhe mats. Damage was difficult to assess, since even severe damage could be hidden by fresh uluhe growth.

Improved access, fence construction and maintenance, and aggressive removal of pigs, are all integral components of a successful ungulate control program. Attempts to reduce pig populations to remnant levels in terrain similar to the Reserve's without any fences have not been effective, as animals can move into areas where population densities were reduced. Funds spent on feral pig control will be ineffective unless population size can be reduced to low levels and not allowed to build back up.

Alternative Actions and Probable Impacts:

1) No action. Accept the continuing deterioration of Puu o Umi's forest watershed and native resources. Without control, pigs degrade native communities, lower biological diversity, and increase non-native plant invasion.

2) Attempt control of feral animals without construction or maintenance of any fences. Impacts of feral pigs under this alternative will probably be roughly the same as alternative #1, except for portions of the Reserve where increased hunting activity may keep pig population down and protect small areas of forest. Pig removal will be less effective without fences to keep new populations from moving into the Reserve.

3) Control feral pigs with the aid of fences. This method has proven successful and beneficial for the preservation of native ecosystems. Recovery of native vegetation has occurred in similar areas where management programs have been implemented. The advance of non-native weed species encouraged by pig disturbance can also been slowed. Native plant species surviving only as epiphytes because of pig disturbance can become re-established on the forest floor.

Recommended Action: Alternative #3 is recommended, and involves three projects: access improvement and shelter construction, fence construction and maintenance, and pig removal.

Project 1 - Access Improvement and Shelter Construction

Improved access is needed to undertake management programs in the Reserve. The only official road for vehicular access to the Reserve is on the far western boundary. There are three vehicular access routes proposed, two of which are through state-leased land. No roads are proposed into the Reserve. NARS staff will work with landowners and state lessees to formalize and improve these access routes. Use of these routes by the general public will be determined on a case-by-case basis.

A Reserve-wide trail system is needed to improve access within the Reserve (Figure 6). These maintained management trails will be well marked and designed to minimize disturbance to the existing vegetation. Portions of certain trails traversing boggy areas will need boardwalks. Helipads will be built and maintained to allow efficient and safe transfer of materials and staff into remote areas. Three management shelters will be built to expedite overnight work trips.

Cost/Workload: The following resources will be needed for access improvement and shelter construction:

Year 1 -	Establish Bog Trail (2.2 mi.)		$ 4,400
	Establish Kawainui Trail (1.6 mi.)		3,200
	Establish Bog Helipad		3,000
	Establish Honokane Nui Helipad		3,000
	Boardwalk Kehena Ditch Trail (3.3 mi.)		19,800
		Total	**$33,400**
Year 2 -	Build Kaunu o Kaleioohie Shelter		$15,000
	Establish Puu o Umi Trail (1.6 mi.)		3,200
	Establish Summit Trail (4.0 mi.)		8,000
	Establish Eke Trail (1.4 mi.)		2,800
	Establish Opaeloa Trail (1.9 mi.)		3,800
	Establish Puu Ahia Trail (1.2 mi.)		2,400
	Establish Kaunu o Kaleioohie Helipad		3,000
	Improve access to Kehena Trail (1.6 mi.)		1,600
	Improve Kahua Ranch Access Rd (2.3 mi.)		26,000
		Total	**$65,800**
Year 3 -	Build Honokane Nui Shelter		$15,000
	Establish Waipahoehoe Loop Trail (2.9 mi.)		5,800
	Establish Waiaka Trail (1.2 mi.)		2,400
	Improve Laupahoehoe Trail (4.8 mi.)		4,800
	Improve Puu Kawaiwai Access Road (1.8 mi.)		27,000
		Total	**$55,000**
Year 4 -	Improve Waiilikahi Shelter		$10,000
	Boardwalk sections of established trails (4.0 miles)		32,000
	Improve Waiaka Access Road (1.6 mi.)		24,000
		Total	**$66,000**
Year 5 -	Maintain Access Roads (5.7 mi.)		$ 8,550
	Maintain Trails (24.4 mi.)		2,440
	Maintain Boardwalk (7.3 mi.)		2,190
	Maintain 3 Shelters		1,200
	Maintain 4 Helipads		800
		Total	**$15,180**
Year 6 -	Same as Year 5	**Total**	**$15,180**

Costs are based $2,000 per mile for trail establishment ($1,000 per mile for existing trail improvement) and $100 per mile per year for maintenance, $8,000 per mile for boardwalk establishment and $300 per mile per year for maintenance, $10,000 - 15,000 per mile for road access improvement and $1,500 per mile per year for maintenance, $3,000 for helipad establishment and $200 per helipad per year for maintenance, and $15,000 for shelter establishment ($10,000 for improvement of existing shelter) and $400 per year per shelter for maintenance. The majority of this work can be done on contract supplemented with the use of volunteers.

Project 2 - Fence Construction and Maintenance

Fencing strategies are dictated by the topographic nature of the Reserve and the priority of resources threatened. Natural barriers should be used whenever possible. Three management units are proposed for fencing.

The first is the 630-acre Bog Management Unit which contains two rare and undisturbed natural communities. A one-mile fence will close off the unit by taking advantage of the natural barriers presented by the steep palis of Waimanu and Waipio valleys on three sides.

The Puu o Umi and Opaeloa Management Units are also proposed for fencing. These units encompass 2,590 acres and are the heart of the Reserve and contain relatively undisturbed native forest ecosystems. A progressive fencing strategy will be used over three years to allow development of shelter and trail infrastructure. This will also allow time for staff hunting to remove as many pigs as possible inside the units before they are closed off. Pig removal in conjunction with fencing is important to take advantage of induced pig movement. It also avoids restriction of animals in one location which can cause heavy localized damage.

Careful clearing of fence lines is needed to minimize disturbance to existing vegetation. All clothing and equipment will be cleaned to avoid spreading or introducing non-native plants and invertebrates. A botanist will walk the flagged fence route to locate and flag rare plants to be avoided by the brushing crew.

Ideally, fences should be inspected and maintained monthly or after major storms. However, the remoteness and inclement weather of the Reserve may make this impractical. Maintenance is planned for six times a year. Inspections will be done in conjunction with other resource management activities such as ungulate removal, monitoring, and non-native plant control. All priority weed species found along fence lines will be removed.

Cost/Workload: The following resources will be needed to construct fences:

Year 1 -	Bog Fence (1.0 mi.)	**Total**	**$ 35,000**
Year 2 -	Puu Ahia Trail Section (1.4 mi.) Summit Trail Section (2.0 mi.)	**Total**	**$119,000**
Year 3 -	Puu o Umi Trail Section (1.6 mi.) Kawainui Trail Section (1.6 mi.)	**Total**	**$112,000**
Year 4 -	Kehena Ditch Section (2.0 mi.)	**Total**	**$ 70,000**

Costs are based on $35,000 per mile for fences. Costs include materials, supplies, and labor for fence line preparation (brushing and clearing of proposed fence line), contractor logistics, and actual construction. Strict procedures for clearing fence routes will be established to minimize disturbance to vegetation, ground cover, and introduction of weeds. A botanist will search planned fence locations for rare plants and notify crew clearing the fence line.

Cost/Workload: The following annual workload is projected for fence inspection six times a year:

Year 1 -	1.0 mile of fence line Technician 12 Person Days (PD) Supplies and Support	 $ 	 840 500
		Total	**$ 1,340**
Year 2 -	4.4 miles of fence line Technician 53 PD Supplies and Support	 $ 	 3,710 2,200
		Total	**$ 5,910**
Year 3 -	7.6 miles of fence line Technician 92 PD Supplies and Support	 $ 	 6,440 3,800
		Total	**$10,240**
Year 4-6	9.6 miles of fence line Technician 116 PD Supplies and Support	 $ 	 8,120 4,800
		Total	**$12,920**

Costs are based on a two-person crew able to inspect and fix one mile of fence per day. Supplies for fence maintenance are estimated at $500 per mile per year. Salaries are $70 per person per day. Fences will be inspected six times per year. Inspections will be done in conjunction with other management activities such as monitoring, pig and non-native plant control.

Project 3 - Pig Removal

NARS staff involvement will be required in all Reserve ungulate control programs. Activities will range from organizing "special" public hunts to direct removal of animals in specific management units of the Reserve.

Public hunting can be a viable tool for control, especially in the early stages of a Reserve-wide program. Project 1 outlines a system of management trails and shelters that will help improve access to make public hunting a viable tool for control. The maintained hunting trails will direct and distribute hunting pressure. Volunteer groups can play an important role in establishing and maintaining forest trails in the Reserve (see Priority #4 - Volunteer Support Program).

Special hunts to concentrate on specific portions of a Reserve is another effective tool. These hunts will also allow NARS managers to monitor hunting success and collect biological data on harvested animals. Priority management units proposed for staff control of pigs over the next six years comprise only one-third of the Reserve. This points out the need to incorporate public hunting within the Reserve pig control program in certain areas. These areas include the Puu Ahia, Kahakohau, and the Upper and Lower Waiiliikahi management units, which encompass over 6,900 acres.

Although public hunting may be used as an interim measure, staff will be directly responsible for pig removal in the Puu o Umi, Opaeloa, and the Bog management units. Hunting with dogs is an effective control tool and will be used in unfenced units that are not suitable for snaring and for clearing out pigs from planned fenced areas. Hunting may be alternated with snaring in intensive control units.

Snaring has proven to be an effective pig control tool, especially in remote forested regions like the Puu o Umi Reserve. The Puu o Umi and the Opaeloa management units are ideally suited for this control technique. Snaring is most effective in areas with a combination of well-utilized pig trails, topographic features that will channel movements, and trees to anchor the snares. The most effective approach is to set snares and leave the area unattended to minimize the effect of human presence, returning later to assess the success and condition of the snares. Fences will restrict pig movement in the Reserve and create good snaring opportunities along fence lines. Snares in rain forests last six months to a year.

Public access will be restricted and signs posted in all areas where snares are set. Snare locations will be mapped, adequately marked in the field, and snares set to avoid harm to non-target species. Snares should be checked as frequently as

possible. If found alive, pigs caught in snares should be disposed of as humanely as possible. Data on health, sex, and age of captured pigs will be recorded to determine effectiveness of the snaring program.

Shooting pigs from helicopters, which is appropriate only in special cases, is recommended for the Bog Management Unit. This unit is remote, contains valuable biological resources, a low pig population, and low-stature vegetation which allows good visibility and use of infrared spotters. The infrared spotter is heat sensitive and is used in the early morning before the sun has heated up the surrounding lands. The warmth of the pig's body shows up on the screen and the aircraft can move directly to its location and make visual contact. Helicopter use in this Bog Management Unit will minimize damage to the wet, boggy area by avoiding trampling of vegetation and reducing the accidental introduction of weed seeds. Training and safety considerations are essential for this work.

Cost/Workload: The following resources will be needed to conduct the pig removal project:

Pig removal activities in year 1 will consist of 25 days of staff hunting (2 person crew), 20 days of special hunts for the general public (2 person crew), and 10 hours of helicopter hunting (2 person crew).

Year 1:	Helicopter (10 hours)		$ 7,500
	Personnel - Res. Manager 11 PD		935
	Technician 83 PD		5,810
	Supplies and Support		2,500
		Total	**$14,245**

Pig removal activities in year 2 will be similar to year 1 with an addition of 500 acres of snaring.

Year 2:	Helicopter hunting (10 hours)		$ 7,500
	Personnel - Res. Manager 11 PD		935
	Technician 101 PD		7,070
	Supplies and Support		3,700
		Total	**$19,205**

Pig removal activities in year 3 will be similar to year 2 with an additional 500 acres of snaring and only 6 hours of helicopter hunting.

Year 3:	Helicopter hunting (6 hours)		$ 4,500
	Personnel - Res. Manager 11 PD		935
	Technician 119 PD		8,330
	Supplies and Support		4,900
		Total	**$18,665**

Control of priority weed species in key management units will be necessary. Priority weed species found in the Reserve include broomsedge (Andropogon virginicus), kahili ginger (Hedychium gardnerianum), yellow ginger (Hedychium flavescens), palm grass (Setaria palmifolia), blackberry (Rubus argutus), banana poka (Passiflora mollissima), and Tibouchina herbacea, which was found just outside of the Reserve.

Manual and chemical weed control methods are costly and priorities for their use set by the nature of the weed, the value of the area it is invading, and the effectiveness of the control measure. Biocontrol is an important potential tool in the management of wide spread priority weed species. The NARS should support interagency biocontrol projects, especially for banana poka, by lobbying where appropriate and providing research sites and logistical support.

Non-native plant invasions observed during the survey varied in each community type. Much of the Mixed Grass and Sedge and `Ohia Mixed Montane Bogs were weed-free. However, a pig-disturbed section of the bog contained an incipient population of broomsedge (Andropogon virginicus), and also a few individuals of fireweed (Erechtites valerianifolia). Very few non-native plants were observed in the `Ohi`a Mixed Montane Bog, however, a few non-flowering individuals of kahili ginger were found and uprooted. Other incidentals included Juncus planifolius and broomsedge but neither were common, and both tended to occur only at the edges of the bog. The central portion of the bog was pristine.

The steep slopes on which the fern/shrub cliff community grows are subject to erosion. These disturbed areas are sites for non-native plant invasions, which included Ageratina riparia, palm grass, thimbleberry (Rubus rosifolius), and a variety of grasses. In some areas, yellow ginger was abundant. There were few non-native plants in the `Ohi`a Mixed Shrub Montane Wet Forest community, but ubiquitous species such as Juncus planifolius and Polygonum punctatum were observed in pig-disturbed areas. The dense canopy and crowded understory in less disturbed portions hinders shade-intolerant weeds from successful invasion.

In the `Ohi`a/`Olapa Montane Wet Forest, non-native plants included several species of grass and sedge, especially Juncus planifolius and carpetgrass (Axonopus fissifolius), as well as herbs such as fireweed, gosmore (Hypochoeris radicata), Polygonum punctatum, and St-Johnswort (Hypericum mutilum). Several other non-native species were confined to trails and the Reserve boundary along pastures. Thimbleberry was seen in areas of old pig disturbance, and was widespread in parts of the Reserve. Blackberry and banana poka were found above the pastures of

Waimea in `ohi`a/`olapa forest, and together represent the greatest weed threat to the Reserve. An incipient population of Tibouchina herbacea was found near the beginning of Transect 4, just outside the Reserve boundary.

Non-native plants are infrequent in the `Ohi`a/Uluhe Montane Wet Forest, which provides a good buffer between disturbed areas, and intact forests deeper in the Reserve. The thick root mat of the uluhe seems to inhibit invasion by non-native plants.

Alternative Actions and Probable Impacts:

1) Control pigs, but do not attempt to control any priority non-native plant species. This will reduce the spread of many pig-dispersed plant species, but will allow continued advance of plants spread by birds and people. Decreased rooting and disturbance to the forest floor by feral pigs will slow down establishment of many non-native plants, but already established plants may continue to spread unchecked. A few especially aggressive weeds could overwhelm large areas.

2) Control priority non-native weed species in the key management areas before they become widely established. Set up monitoring transects to locate other incipient populations of priority weed species. Management measures would include selective use of approved herbicides and manual removal with hand tools.

3) Control all non-native plant species in the Reserve. This alternative would require substantial resources and is not practical.

Recommended Action: Alternative #2 is recommended. Non-native plant removal of priority weeds along trails and fences should occur as part of periodic maintenance. The incipient populations of Tibouchina herbacea, blackberry, and broomsedge should be removed as soon as possible. All priority weeds should be manually removed from the pristine bogs.

The infestation of banana poka is limited to the lower boundaries of the Reserve. The poka is too widespread for eradication, but attempts need to be made to keep it from spreading. Infestations should be mapped accurately. Control of mature poka plants should start from the highest elevation of infestation.

The key to checking the spread of poka in the Reserve is pig control. Although both pigs and birds disperse weed seeds, successful seedling establishment seems limited to pig disturbed areas. Pig trails and activity leading from these infestation centers of banana poka should be monitored and poka seedlings found should be removed. Aggressive hunting pressure in

infestation centers will help. Volunteer groups can play a key part in the control of banana poka in the Reserve. (See Priority #4 - Volunteer Support.)

Detailed records of the effectiveness of control methods used in the Reserve will be kept. Coordination between NARS and other involved agencies in plant control work will reduce management costs. Strict precautions will be taken to ensure management personnel do not transport weed seeds into the Reserve on their shoes or equipment (including helicopters). Hikers and hunters will be informed of these inadvertent introductions by posted signs along access trails into the Reserve.

Cost/Workload:

Year 1 - Personnel	- Res. Manager 10 PD		$ 850
	Technician 60 PD		4,200
Supplies and support			$ 8,000
		Total	**$13,050**
Year 2-6 same as Year 1		**Total**	**$13,050**

Salaries are $85 a day for Reserve manager and $70 a day for technicians. Supplies and support include hand tools, herbicides, and logistical support for volunteer labor.

Priority #3 - Monitoring Program (PUO-RM-03)

GOAL: Monitor the effectiveness of management projects and track significant ecological changes through long-term scientific monitoring.

Statement of the Problem: Management activities may not always achieve predicted results and management efficiency needs to be judged. Monitoring changes in non-native and native plant distribution, and animal species abundance entails recording specific data at permanent points and transects in the Reserve. Monitoring also documents progress and facilitates refinement of management techniques employed in the Reserve.

Alternative Actions and Probable Impacts:

1) No monitoring program. This could lead to inefficient management resulting from poor understanding of the area's biological needs.

2) Conduct ad hoc monitoring whenever possible. This is likely to be considerably less effective in the long run than a systematic approach.

3) Establish systematic monitoring programs for ungulate damage, non-native weed invasion, native vegetation recovery, and status

of rare species. Increase monitoring intensity for select problems and areas as needed.

Recommended Action: Alternative #3 is recommended. Develop monitoring programs to evaluate effects of management activities and identify future management needs. Many transects will require a two-person crew for safety. Two-person monitoring crews may be dropped off by helicopter in remote areas, take data at established monitoring points, and hike out. Specific goals of the program are to determine:

1) the effectiveness of staff and public hunting in reducing ungulate damage;
2) the success of priority weed species control;
3) the location of incipient populations of other priority weeds; and
4) status of known rare species. Some monitoring activities will be done in conjunction with fence inspection.

Cost/Workload: The following resources will be needed to conduct the monitoring project:

Year 1 - Personnel	- Res. Manager 20 PD	$ 1,700
	Technician 20 PD	1,400
Helicopter (4 trips and reconnaissance)		2,200
Supplies and support		$ 6,000
	Total	**$11,300**
Year 2-6 same as Year 1	**Total**	**$11,300**

Salaries are $85 a day for Reserve manager and $70 a day for technicians. Supplies and support include film and development, software development, and office supplies.

Priority #4 - Public Education and Volunteer Program (PUO-RM-04)

GOAL: To build public understanding and support for the Reserve and the NARS in the local community. Educational opportunities will be provided for interested groups. Volunteer labor to help staff in management activities will be recruited.

Statement of the Problem: The population of the Big Island, and especially the Waimea-Kohala area, has increased rapidly. In light of this development, there is strong public sentiment to conserve what is left of the native Hawaiian heritage. Many new and old residents in the Kohala area are unaware of Hawaii's natural heritage and the Puu o Umi Reserve. Even fewer realize that native resources and the benefits they provide are being threatened. Management of this Reserve will be a long-term effort, and public support and involvement is necessary.

The pristine portions of the Reserve are invaluable for baseline research as examples of undisturbed Hawaiian ecosystems. Public use of these areas should not be encouraged, and in certain areas may need to be controlled (e.g. the Bog Management Unit). The general public needs to know the importance of these areas and the management activities necessary to protect them. Public education through appropriate media coverage is crucial, without encouragement of unrestricted public use of these fragile areas. Special efforts to communicate with public hunters who have traditionally used these areas will be necessary.

Volunteer groups have proven successful in certain natural area management activities, especially in labor intensive efforts such as fence construction, weed control, and trail maintenance. These groups tend to be extremely motivated, representing a valuable resource for the Reserve manager.

Alternative Actions and Probable Impacts:

1) Do not attempt to inform the general public about the resources protected in the Reserve or explain reasons for specific management actions. Do not use volunteer groups in relevant management activities in the Reserve. The results of this alternative could include less public and legislative support for the NARS, misunderstanding among certain groups resulting in vandalism of capital improvements, and increased costs for overall NARS management, especially in plant control work.

2) Maintain community outreach program to give public presentations, provide informational material, and utilize concerned volunteer groups. This could result in cooperation with the general public in feral pig and non-native plant control programs and result in less expensive yet more effective management results. It could also provide a local constituency that would support Reserve management activities.

Recommended Action: Alternative #2 is recommended. Inform the general public about resources within the Reserve and management activities through television, newspaper, and other local media outlets. Present slide shows and talks to community groups. Develop a brochure that describes the resources and ongoing management activities within the Reserve. Establish a self-guided nature trail along the Waipahoehoe Loop Trail.

Utilize volunteer groups for Reserve management whenever feasible. Reserve staff hours will be adjusted so personnel are available to supervise volunteer work groups, especially on weekends. Eventually, leaders from volunteer groups can be trained to supervise their volunteer crews.

Cost/Workload:

Year 1 -	Personnel -	Res. Manager 10 PD	$ 850
		Technician 10 PD	700
	Supplies and	support	$ 1,000
		Total	**$ 2,500**
Year 2 -	Personnel -	Res. Manager 10 PD	$ 850
		Technician 10 PD	700
	Brochure		10,000
	Supplies and	support	$ 1,000
		Total	**$12,550**
Year 3 -	Personnel -	Res. Manager 10 PD	$ 850
		Technician 10 PD	700
	Nature Trail	Development	15,000
	Supplies and	support	$ 1,000
		Total	**$17,550**
Year 4-6	Same as year 1	**Total**	**$ 2,500**

D. Boundary Administration and Special Uses

Participation and cooperation among all adjacent landowners is an important factor for effective management of the Puu o Umi Reserve. A Kohala management committee should be established and composed of representatives from affected state/private landowners and other concerned groups. The committee's goal will be to coordinate current management activities, share management expertise, plan future cooperative management efforts, and disseminate information to the general public for the entire Kohala summit region. This plan will be sent to all involved parties and NARS staff will take the lead in coordinating this cooperative effort.

The Na Ala Hele program offers an excellent vehicle to formalize certain key access routes, and NARS staff should work closely with this trails and access program.

IV. BUDGET SUMMARY

When this plan was prepared, the long-term funding and organizational structure of the NARS had not been settled. Coordination and implementation of priority projects among the 18 Reserves may be affected by future organizational and funding decisions. This may require some revision in the priority projects described here.

A six-year implementation schedule is presented to accomplish management goals as efficiently as possible. Four management programs are proposed to achieve this. Although listed by priority, they build upon each other to form an integrated strategy.

The budget summary is based on a NARS integrated within the Division of Forestry and Wildlife. The budget summary shown is for the management of the Puu o Umi Reserve only. It does not include all the administrative, clerical, and facility support needed to run a state-wide NARS or to manage the other seven natural area reserves on the island of Hawaii. These infrastructure costs for the NARS will be identified and documented separately.

The initial costs of starting up a management program in a Reserve the size of Puu o Umi are high, especially fence construction. Once initial capital improvements are completed, annual costs will decrease as indicated by totals for years 5 and 6. Expenses for purchase, operation and maintenance of two 4-wheel drive vehicles with radios and three portable radios are included in program PUO-OP-01. Starting with year 3, an 1 percent inflation increase is incorporated into each yearly total, with an additional 1 percent each subsequent year (e.g. year 3 includes 1 percent, year 4 includes 2 percent, year 5 includes 3 percent, etc.).

BUDGET SUMMARY
PUU O UMI NATURAL AREA RESERVE

PROGRAM	YR 1	YR 2	YR 3*	YR 4*	YR 5*	YR 6*
PUO-RM-01						
Proj. 1	33,400	65,800	55,000	66,000	15,200	15,200
Proj. 2	36,300	124,900	122,200	82,900	12,900	12,900
Proj. 3	14,200	19,200	18,700	21,100	22,100	24,500
PUO-RM-02	13,100	13,100	13,100	13,100	13,100	13,100
PUO-RM-03	11,300	11,300	11,300	11,300	11,300	11,300
PUO-RM-04	2,500	12,600	17,600	2,500	2,500	2,500
PUO-OP-01	54,000	5,000	5,000	5,000	5,000	5,000
TOTAL ($)	**164,800**	**251,900**	**245,300**	**205,900**	**84,600**	**87,900**

MANAGEMENT PROGRAMS
PUO-RM-01 - Ungulate Control (Priority 1)
Project 1 - Access Improve./Shelter Construct.
Project 2 - Fence Construct. and Maintain.
Project 3 - Feral Pig Removal
PUO-RM-02 - Non-native Plant Control (Priority 2)
PUO-RM-03 - Monitoring (Priority 3)
PUO-RM-04 - Public Education and Volunteer Support(Priority 4)
PUO-OP-01 - Infrastructure Expenses

PERSONNEL (PD = person days)

YR 1 -	Reserve manager 51 PD	YR 4 -	Reserve manager 51 PD
	Technician 185 PD		Technician 343 PD
YR 2 -	Reserve manager 51 PD	YR 5 -	Reserve manager 51 PD
	Technician 244 PD		Technician 361 PD
YR 3 -	Reserve manager 51 PD	YR 6 -	Reserve manager 51 PD
	Technician 301 PD		Technician 379 PD

* Starting with year 3, a 1 percent inflation increase is incorporated into each yearly total, with an additional 1 percent each subsequent year (e.g. year 3 includes 1 percent, year 4 includes 2 percent, year 5 includes 3 percent, etc.).

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APPENDIX 1
Puu O Umi Natural Area Reserve
Transect Specifications

Transect number	Transect length (ft)	No. of substations	Natural communities surveyed
1	984	7	`Ohi`a/`Olapa Montane Wet Forest
2	1,968	13	`Ohi`a Mixed Montane Bog `Ohi`a/`Olapa Montane Wet Forest Uluhe Successional Shrubland
3	4,428	28	Carex alligata Montane Wet Grassland `Ohi`a /Mixed Shrub Montane Wet Forest `Ohi`a/`Olapa Montane Wet Forest
4	2,952	19	Mixed Grass and Sedge Montane Bog `Ohi`a/`Olapa Montane Wet Forest
5	2,460	16	`Ohi`a/`Olapa Montane Wet Forest
6	1,312	9	`Ohi`a/`Olapa Montane Wet Forest `Ohi`a/Uluhe Montane Wet Forest
X	N/A	1	`Ohi`a/`Olapa Montane Wet Forest
Y	N/A	1	`Ohi`a/`Olapa Montane Wet Forest
Z	N/A	1	`Ohi`a/`Olapa Montane Wet Forest

Survey Participants

Lyman Abbott, TNCH, Ecological Assistant
Michael Buck, DOFAW, Survey Forester
Winona Char, TNCH (contracted), Assistant
Samuel Gon III, TNCH, Ecologist

TNCH = The Nature Conservancy of Hawaii
DOFAW= State Division of Forestry & Wildlife, Department of Land and Natural Resources.

APPENDIX 2

Puu O Umi Natural Area Reserve
Sample Field Forms

NATURAL COMMUNITY FIELD OBSERVATION FORM TIME START:_____ END:_____
DATE:_____ TRANSECT#:_____ STATION#:_____ ELEVATION:_____
OBSERVER(S):_____
NC NAME:_____ EOCODE:_____
NAR NAME:_____ QUAD NAME:_____
SUBSTRATE:_____
ADJ NCS:_____

DESCRIPTION LINE:_____

ASPECT	SLOPE	CANOPY CLOSURE	TOPOGRAPHIC POSITION	CANOPY STATURE	MOISTURE	NC AREA
___N	__FLAT	__DENSE	__CREST	__<1M	__INUNDATED	__<1 AC
___E	__GENTLE	__CLOSED	__UPPER SLP	__1-2.5M	__SATURATED	__1-5 AC
___S	__MOD	__OPEN	__MID SLP	__2.5-5M	__MOIST	__6-10 AC
___W	__STEEP	__SCATTER	__LOW SLP	__5-10M	__MOIST-DRY	__>10 AC
__( )	__VERT	__VERY SC	__BOTTOM	__>10M	__DRY	__( )

*COVER CLASS CODES: 1 = <1% 2 = 1-5% 3 = 5-25%
(FOR USE BELOW) 4 = 25-50% 5 = 50-75% 6 = 75-90% 7 = >90%

A. CANOPY DOMINANTS:

SPECIES	T	S	H	*COVER	AVE DIA	REMARKS

B. SUBCANOPY DOMINANTS:

SPECIES	T	S	H	*COVER	REMARKS

% LITTER:_____ % BARE GROUND:_____ SPECIES LIST ATTACHED: Y N
THREATS:_____

PROTECTION/MANAGEMENT RECOMMENDATIONS:_____

EORANK:_____ A = EXCELLENT B = FAIR-GOOD C = POOR D = DEGRADED
EO BOUNDARIES MAPPED: Y N MAP ATTACHED: Y N PHOTO ##:_____

PLANT FIELD OBSERVATION FORM

NAR NAME:_____ QUAD NAME:_____
DATE:_____ ISLAND:_____ SITE NAME:_____
SPECIES NAME:_____
OBSERVER(S):_____
PHOTO TAKEN:____ Y____ N
SPECIMEN #,COLLECTOR,REPOSITORY:_____
DIRECTIONS:_____

ELEVATION:_____
GENERAL DESCRIPTION OF AREA:_____

EODATA:_____

NATURAL COMMUNITY:_____
ASSOCIATED NATIVE SPECIES:_____

ASSOCIATED WEED SPECIES:_____

THREATS:_____

PROTECTION/MANAGEMENT RECOMMENDATIONS:_____

COMMENTS:_____

ASPECT	SLOPE	LIGHT	TOPOGRAPHIC POSITION	MOISTURE	DOMINANT SPECIES	%COVER
___N	__FLAT	__DENSE	__CREST	__INUNDATED		
___E	__GENTLE	__CLOSED	__UPPER SLP	__SATURATED		
___S	__MOD	__OPEN	__MID SLP	__MOIST		
___W	__STEEP	__SCATTER	__LOW SLP	__DRY-MESIC		
__( )	__VERT	__VERY SC	__BOTTOM	__DRY		

HABIT	PHENOLOGY	AGE STRUCTURE	VIGOR	FREQUENCY	POPULATION SIZE	POPULATION AREA (M^2)
__TREE	__IN LEAF	__%SDLGS	__DYING	__COMMON	__ACTUAL	__1
__SHRUB	__IN BUD	__%IMM	__FEEBLE	__OCCAS	__1-10	__1-5
__HERB	__IN FLOWER	__%MAT	__NORMAL	__RARE	__10-50	__5-10
__VINE	__IMM FRUIT	__%SENESC	__VIGOROUS	__SOL	__50-100	__10-100
__PROST	__MAT FRUIT				__100-1000	__100+
	__DORMANT				__1000+	

TRANSECT STATION FIELD FORM Time Start: _____ End: _____ Date: _____
NC Name: _____ NAR Name: _____
Observer(s): _____
Transect#: _____ Station#: _____ Elevation: _____ Bearing: _____
Description Line: _____ Photo ##: _____
INCIDENTAL OBSERVATIONS:
CHK ITEM: REMARKS:

	Birds	
	Native Inverts	
	Small Mammals	
	Non-native Inverts	
	Fire	
	Erosion	
	Human Influence	
	Add'l Survey Needs	

ASPECT	SLOPE	CANOPY CLOSURE	TOPOGRAPHIC POSITION	CANOPY STATURE	SOIL MOISTURE
__ NORTH	__ FLAT	__ DENSE	__ CREST	__ <1 M	__ INUNDATED
__ EAST	__ GENTLE	__ CLOSED	__ UPPER SLP	__ 1-2.5 M	__ SATURATED
__ SOUTH	__ MOD	__ OPEN	__ MID SLP	__ 2.5-5 M	__ MOIST
__ WEST	__ STEEP	__ SCATTER	__ LOW SLP	__ 5-10 M	__ MOIST-DRY
__( )	__ VERT	__ VERYSC	__ BOTTOM	__ >10 M	__ DRY
__ NO CHG	__ NO CHG	__ NO CHG	__ NO CHG	__ NO CHG	__ NO CHG

Additional notes:

TRANSECT STATION FIELD FORM Time Start: _____ End: _____ Date: _____
NC Name: _____ NAR Name: _____
Observer(s): _____
Transect#: _____ Station#: _____ Elevation: _____ Bearing: _____
Description Line: _____ Photo ##: _____
INCIDENTAL OBSERVATIONS:
CHK ITEM: REMARKS:

	Birds	
	Native Inverts	
	Small Mammals	
	Non-native Inverts	
	Fire	
	Erosion	
	Human Influence	
	Add'l Survey Needs	

ASPECT	SLOPE	CANOPY CLOSURE	TOPOGRAPHIC POSITION	CANOPY STATURE	SOIL MOISTURE
__ NORTH	__ FLAT	__ DENSE	__ CREST	__ <1 M	__ INUNDATED
__ EAST	__ GENTLE	__ CLOSED	__ UPPER SLP	__ 1-2.5 M	__ SATURATED
__ SOUTH	__ MOD	__ OPEN	__ MID SLP	__ 2.5-5 M	__ MOIST
__ WEST	__ STEEP	__ SCATTER	__ LOW SLP	__ 5-10 M	__ MOIST-DRY
__( )	__ VERT	__ VERYSC	__ BOTTOM	__ >10 M	__ DRY
__ NO CHG	__ NO CHG	__ NO CHG	__ NO CHG	__ NO CHG	__ NO CHG

Additional notes:

TRANSECT SUBSTATION FIELD FORM Time Start: _____ End: _____ Date: _____
NC Name: _____
NAR Name: _____ Transect#: ___
Observer(s): _____
*COVER CLASS CODES: 1 = <1% 2 = 1-5% 3 = 5-25%
(FOR USE BELOW) 4 = 25-50% 5 = 50-75% 6 = 75-90% 7 = >90%

STATION NUMBER:

ITEM:																		
UNGULATES:																		
PIGS																		
GOATS																		
CATTLE																		
DEER																		
CANOPY CHANGES:																		
RARE PLANTS:																		
BEARING																		

APPENDIX 3
Puu O Umi Area
Vascular Plant Species List

This species list was compiled from available literature sources, personal communication with botanists familiar with the area (backed by specimen verification for rare plants), and field identification during this NARS field survey. Rare plants (less than 3,000 individuals, or known from fewer than 20 locations worldwide) with specific location information are noted by '+' and are either in the Reserve or its adjacent area (see the rare plants table for those confirmed in the Reserve). Rare plants thought to occur in the Reserve but which lack specific location information, are noted by '#' in the status column.

Due to subjective location information, some non-rare species included on this list may not actually be in the Reserve. Plants and their associated vegetation types reported from literature for the area, but not confirmed during this survey, are noted with an 'x'. Plants reported for the area without an associated vegetation type are assigned to the natural community they would most likely occur in with a '?'.

Descriptions of the natural communities are in the text. Taxonomy follows Wagner et al. (in press) and Wagner and Wagner (1987).

Status	Taxon	*Carex alligata* Montane Wet Grassland	Mixed Grass and Sedge Montane Bog	Mixed Fern/Shrub Montane Wet Cliffs	'Ohi'a Mixed Montane Bog	'Ohi'a Mixed Shrub Montane Wet Forest	'Ohi'a/'Olapa Montane Wet Forest	'Ohi'a/Uluhe Montane Wet Forest	Uluhe Successional Shrubland
E	Adenophorus hymenophylloides					*	*		
E	Adenophorus pinnatifidus					*	*		
E	Adenophorus tamariscinus					*	*		*
N	Ageratina adenophora	?	?	?	?	?	?	?	?
N	Ageratina riparia						*		
N	Ageratum conyzoides	?	?	?	?	?	?	?	?
I	Agrostis avenecea			*			*		
N	Alnus nepalensis						*		
E	Alyxia oliviformis					*	*		
N	Anagallis arvensis						*		
N	Andropogon virginicus	*	*		*		*		*
N	Anthoxanthum odoratum	*					*		
E	Antidesma platyphyllum					?	?	?	?
E	Asplenium acuminatum					*	*		

+ = Rare N = Non-native I = Indigenous E = Endemic

* = Confirmed in NARS field study x = Cited in literature sources
? = Cited in literature; needs confirmation in natural community

Status	Taxon	Carex alligata Montane Wet Grassl	Mixed Grass and Sedge Montane Bog	Mixed Fern/Shrub Montane Wet Cliffs	ʻOhiʻa Mixed Montane Bog	ʻOhiʻa Mixed Shrub Montane Wet Forest	ʻOhiʻa/ʻOlapa Montane Wet Forest	ʻOhiʻa/Uluhe Montane Wet Forest	Uluhe Successional Shrubland
E	Asplenium contiguum					*	*	*	
I	Asplenium horridum					*	*		
I	Asplenium lobulatum					*	*	*	
I	Asplenium polydon	?	?	?	?	?	?	?	?
I	Asplenium unilaterale	*				*	*		
E	Astelia menziesiana						*	*	
N	Athyrium japonicum					*	*		
E	Athyrium microphyllum					*	*		
E	Athyrium sandwichianum	*					*	*	*
N	Axonopus fissifolius	?		?		?	?	?	?
N	Bambusa sp.						*		
I	Blechnum occidentale		x		x	x	x		x
N	Briza minor			*		*	*	*	
E	Broussaisia arguta		x		x	x	x		x
N	Cardamine flexuosa	*				*	*	*	
E	Carex alligata	?	?	?	?	?	?	?	?
N	Centella asiatica		x		x	x	x		
N	Cerastium fontanum	*			*	*	*	*	*
E	Cheirodendron trigynum	*		*		*	*	*	
E	Cibotium chamissoi	*		*	*	*	*	*	
E	Cibotium glaucum						*		
E	Cibotium glaucum x hawaiiense						*		
E	Cibotium hawaiiense						*		
N	Cirsium vulgare	*				*	*		
E	Clermontia calophylla					x	x		
# E	Clermontia drepanomorpha						*		
E	Clermontia parviflora					*	*		
E	Clermontia sp.						*		
E	Clermontia waimeae	?		?		?	?	?	?
N	Colocasia esculenta		x		x	x	x		
N	Commelina diffusa						*		
E	Coniogramme pilosa					*	*		
E	Coprosma ochracea			*		*	*	*	
E	Coprosma pubens								?
N	Cordyline fruticosa	?				?	?	?	?
N	Crassocephalum crepidiodes	?				?	?	?	?
N	Cryptomeria japonica	?				?	?	?	?
N	Cryptotaenia canadensis						*		
E	Ctenitis rubiginosa					*	*	*	
N	Cuphea carthagenensis						*		
E	Cyanea pilosa	?		?	?	?	?	?	?
E	Cyanea pycnocarpa	?		?	?	?	?	?	?
# E	Cyanea tritomantha		x		x	x	x		
N	Cynodon dactylon						*		
N	Cyperus halpan								

+ = Rare N = Non-native I = Indigenous E = Endemic

* = Confirmed in NARS field study x = Cited in literature sources
? = Cited in literature; needs confirmation in natural community

Status	Taxon	Carex alligata Montane Wet Grassl	Mixed Grass and Sedge Montane Bog	Mixed Fern/Shrub Montane Wet Cliffs	'Ohi'a Mixed Montane Bog	'Ohi'a Mixed Shrub Montane Wet Forest	'Ohi'a/'Olapa Montane Wet Forest	'Ohi'a/Uluhe Montane Wet Forest	Uluhe Successional Shrubland
N	Cyperus pilosus		x		x	x	x		
# E	Cyrtandra kohalae	?		?		?	?	?	?
E	Cyrtandra paludosa						*		
E	Cyrtandra platyphylla						*		
E	Cyrtandra sp.	?		?		?	?	?	?
# E	Delissea parviflora	?				?	?	?	?
E	Deschampsia nubigena						*		
E	Dichanthelium cynodon		*		*				
E	Dichanthelium hillebrandianum		*		*				
I	Dicranopteris linearis			*	*	*	*	*	*
N	Digitaria ciliaris	?	?	?	?	?	?	?	?
N	Digitaria sp.	?	?	?	?	?	?	?	?
+ E	Diplazium molokaiense	x							
E	Diplopterygium pinnatum			*			*	*	*
# E	Doodia lyonii	?	?	?	?	?	?	?	?
N	Drymaria cordata						*		
E	Dryopteris spp.	*				*	*		
E	Dubautia plantaginea			*			*		
N	Ehrharta stipoides	*					*		
I	Elaphoglossum alatum					*	*	*	
I	Elaphoglossum hirtum var. micans					*	*	*	
N	Eleocharis sp.		x		x	x	x		
N	Epilobium billardierianum		x		x	x	x		
E	Eragrostis variabilis						*		
N	Erechtites valerianifolia		*				*		
N	Erigeron bonariensis						*		
N	Eucalyptus robusta						*		
+ E	Eurya sandwicensis						*		
N	Festuca sp.					x	x		
N	Ficus macrophylla		x		x				
N	Ficus rubiginosa		x		x	x	x		
N	Fragaria vesca						*		
N	Fraxinus uhdei		x		x	x	x		
E	Freycinetia arborea					x	x		x
N	Geranium carolinianum		x		x	x	x		
N	Geranium homeanum	?	?	?	?	?	?	?	?
E	Grammitis hookeri					*	*		
E	Grammitis tenella					*	*	*	
N	Grevillea robusta						*		
E	Gunnera petaloidea			*					
N	Hedychium coronarium		x		x	x	x		x
N	Hedychium flavescens			*					
N	Hedychium gardnerianum				*		*		
E	Hedyotis acuminata						*		

+ = Rare N = Non-native I = Indigenous E = Endemic

* = Confirmed in NARS field study x = Cited in literature sources

? = Cited in literature; needs confirmation in natural community

Status	Taxon	Carex alligata Montane Wet Grassl	Mixed Grass and Sedge Montane Bog	Mixed Fern/Shrub Montane Wet Cliffs	ʻOhiʻa Mixed Montane Bog	ʻOhiʻa Mixed Shrub Montane Wet Forest	ʻOhiʻa/ʻOlapa Montane Wet Forest	ʻOhiʻa/Uluhe Montane Wet Forest	Uluhe Successional Shrubland
E	Hedyotis hillebrandii					*	*		
E	Hedyotis terminalis					*	*	*	
# E	Hibiscadelphus hualaiensis								?
N	Holcus lanatus	*					*		
N	Huperzia phyllanthum						*		
N	Hydrocotyle sibthorpioides		x		x	x	x		
N	Hydrocotyle verticillata		x		x	x	x		x
N	Hypericum mutilum	*					*	*	
N	Hypochoeris radicata	*				*	*		
E	Ilex anomala				*	*	*		
E	Isachne distichophylla		*		*		*		*
N	Juncus effusus						*		
N	Juncus ensifolius		x		x		x		
N	Juncus planifolius	*			*	*	*		*
N	Juncus tenuis	*					*		
E	Korthalsella complanata						*		
E	Korthalsella cylindrica				*		*		
N	Kyllinga brevifolia					*	*		
E	Labordia hedyosmifolia				*	*	*		
E	Liparis hawaiensis						*		
# E	Lobelia hypoleuca		x		x	x	x		
N	Ludwigia palustris	?	?	?	?	?	?	?	?
I	Lycopodium cernuum				*	*	*		*
I	Lycopodium venustulum					*	*		
I	Machaerina angustifolia		*		*		*		*
E	Mecodium recurvum	*				*	*	*	
N	Melaleuca quinquenervia						*		
N	Melastoma candidum	?	?	?	?	?	?	?	?
E	Metrosideros polymorpha	*	*	*	*	*	*	*	*
I	Microlepia strigosa						*		
N	Modiola caroliniana		x		x	x	x		
E	Myrsine lessertiana	*			*	*	*	*	*
E	Myrsine sandwicensis					*	*	*	*
I	Nephrolepis cordifolia		x		x	x	x		
N	Nephrolepis multiflora	?	?	?	?	?	?	?	?
E	Nertera granadensis		x		x	x	x		
I	Odontosoria chinensis						*	*	*
I	Ophioglossum pendulum	?	?	?	?	?	?	?	?
I	Oxalis corniculata						*		
N	Panicum repens						*		
N	Paspalum conjugatum						*	*	
N	Paspalum dilatatum	?	?	?	?	?	?	?	?
N	Paspalum fimbriatum		x		x	x	x		
N	Paspalum scrobiculatum	?	?	?	?	?	?	?	?
N	Paspalum urvillei		x		x	x	x		

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Status	Taxon	Carex alligata Montane Wet Grassl	Mixed Grass and Sedge Montane Bog	Mixed Fern/Shrub Montane Wet Cliffs	ʻOhiʻa Mixed Montane Bog	ʻOhiʻa Mixed Shrub Montane Wet Forest	ʻOhiʻa/ʻOlapa Montane Wet Fores	ʻOhiʻa/Uluhe Montane Wet Fores	Uluhe Successiona Shrubland
N	Passiflora mollissima					*	*		
E	Pelea clusiifolia					*	*		*
+ E	Pelea hawaiensis					*	*		
E	Pelea sp.				*		*		
N	Pennisetum clandestinum						*		
# E	Peperomia cookiana						*	*	
E	Peperomia hypoleuca					*	*		*
E	Peperomia macraeana						*		
E	Peperomia membranacea				*		*		
E	Peperomia sp a.						*		
E	Peperomia sp b.			*					
E	Peperomia tetraphylla						*		
E	Perrottetia sandwicensis	?		?		?	?	?	?
+ E	Phyllostegia floribunda	?	?	?	?	?	?	?	?
# E	Phyllostegia longipes	?		?		?	?	?	?
# E	Phyllostegia vestita								*
E	Phytolacca sandwicensis						*		
E	Pilea peploides		x		x	x	x		x
E	Pipturus albidus		x		x	x	x		x
E	Pittosporum hawaiiense				x				
N	Pityrogramma calomelanos		x		x	x	x		
N	Plantago lanceolata						*		
N	Plantago major		x		x	x	x		
# E	Platydesma remyi					?	?	?	
I	Pleopeltis thunbergiana					*	*		
N	Pluchea symphytifolia		x		x	x	x		
N	Poa annua		x		x	x	x		
N	Polygonum punctatum	*				*	*	*	
I	Polypodium pellucidum	*				*	*		
+ E	Pritchardia lanigera								*
N	Prunus cerasifera		x		x	x	x		
N	Psidium cattleianum						*	*	
I	Psilotum complanatum					*	*	*	
I	Psilotum nudum						*		
E	Psychotria hawaiiensis var. hillebrandii						*		
I	Pteris cretica		x		x	x	x		x
I	Pteris excelsa						*		
I	Pycreus polystachyos						*		
N	Ranunculus repens	*					*		
E	Rhynchospora chinensis	*	*		*		*		*
N	Rubus argutus						*	*	
E	Rubus hawaiensis					*	*		
N	Rubus rosifolius			*		*	*	*	
N	Rumex acetosella		x		x	x	x		

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Status	Taxon	Carex alligata Montane Wet Grassl	Mixed Grass and Sedge Montane Bog	Mixed Fern/Shrub Montane Wet Cliffs	'Ohi'a Mixed Montane Bog	'Ohi'a Mixed Shrub Montane Wet Forest	'Ohi'a/'Olapa Montane Wet Forest	'Ohi'a/Uluhe Montane Wet Fores	Uluhe Successiona Shrubland
E	Rumex aff. giganteus						*		
N	Rumex crispus		x		x	x	x		
N	Rumex sp.						*		
N	Sacciolepis indica				*		*		*
E	Sadleria cyatheoides			*					
E	Sadleria pallida			*	*		*		*
E	Sadleria souleyetiana						*		
# E	Schiedea diffusa	?		?		?	?	?	?
N	Sequoia sempervirens						*		
N	Setaria geniculata		x		x	x	x		
N	Setaria palmifolia			*			*		*
N	Setaria verticillata		x		x	x	x		
E	Smilax melastomifolia				*	*	*		
N	Sonchus oleraceus		x		x	x	x		
E	Sphaerocionium lanceolatum						*	*	
E	Sphaerocionium obtusum						*		
N	Sporobolus indicus		x		x	x	x		
E	Stenogyne calaminthoides					*	*		
# E	Stenogyne cranwelliae	?	?	?	?	?	?	?	?
E	Sticherus owhyensis			*			*	*	*
E	Styphelia tameiameiae	*	*	*	*	*	*		
N	Taraxacum officinale						*		
E	Tetraplasandra oahuensis						*		
N	Thelypteris dentata						*	*	
E	Thelypteris sandwichiensis					*	*		
N	Thelypteris torresiana	?	?	?	?	?	?	?	?
N	Tibouchina herbacea						*		
E	Touchardia latifolia								x
E	Trematolobelia grandifolia			*	*	*	*		*
N	Trifolium repens		x		x	x	x		
I	Uncinia uncinata					*	*		
E	Vaccinium calycinum	*		*		*	*	*	*
E	Vaccinium dentatum		*		*				
E	Vandenboschia davallioides					*	*		
N	Verbena litoralis		x		x	x	x		
N	Veronica plebeia						*		
N	Veronica serpyllifolia		x	x	x	x	x		x
E	Viola maviensis				*				
E	Xiphopteris saffordii	*				*	*		
N	Youngia japonica						*	*	

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APPENDIX 4
Puu O Umi Natural Area Reserve
Bird Species List

The birds listed have been reported from visual and audio identification in or near the Reserve. The list includes information on rare birds, compiled from the literature. Taxonomy follows the Checklist of the Birds of Hawaii by R. Pyle (1988).

Status	Species	Common Name	Source
+E	Anas wyvilliana	Koloa, Hawaiian Duck	x
+E	Buteo solitarius	`Io, Hawaiian Hawk	x
N	Cardinalis cardinalis	Northern Cardinal	*
N	Carpodacus mexicanus	House Finch	x
E	Chasiempis sandwichensis sandwichensis	`Elepaio	*
N	Garrulax canorus	Hwamei	*
E	Hemignathus virens virens	`Amakihi	*
E	Himatione sanguinea sanguinea	`Apapane	*
N	Leiothrix lutea	Red-billed Leiothrix	x
N	Lonchura punctulata	Nutmeg Mannikin	x
N	Phasianus colchicus	Ring-necked Pheasant	x
+E	Puffinus newelli	`A`o, Newell Shearwater	x
N	Streptopelia chinensis	Spotted Dove	x
E	Vestiaria coccinea	`I`iwi	*
N	Zosterops japonicus	Japanese White-eye	*

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